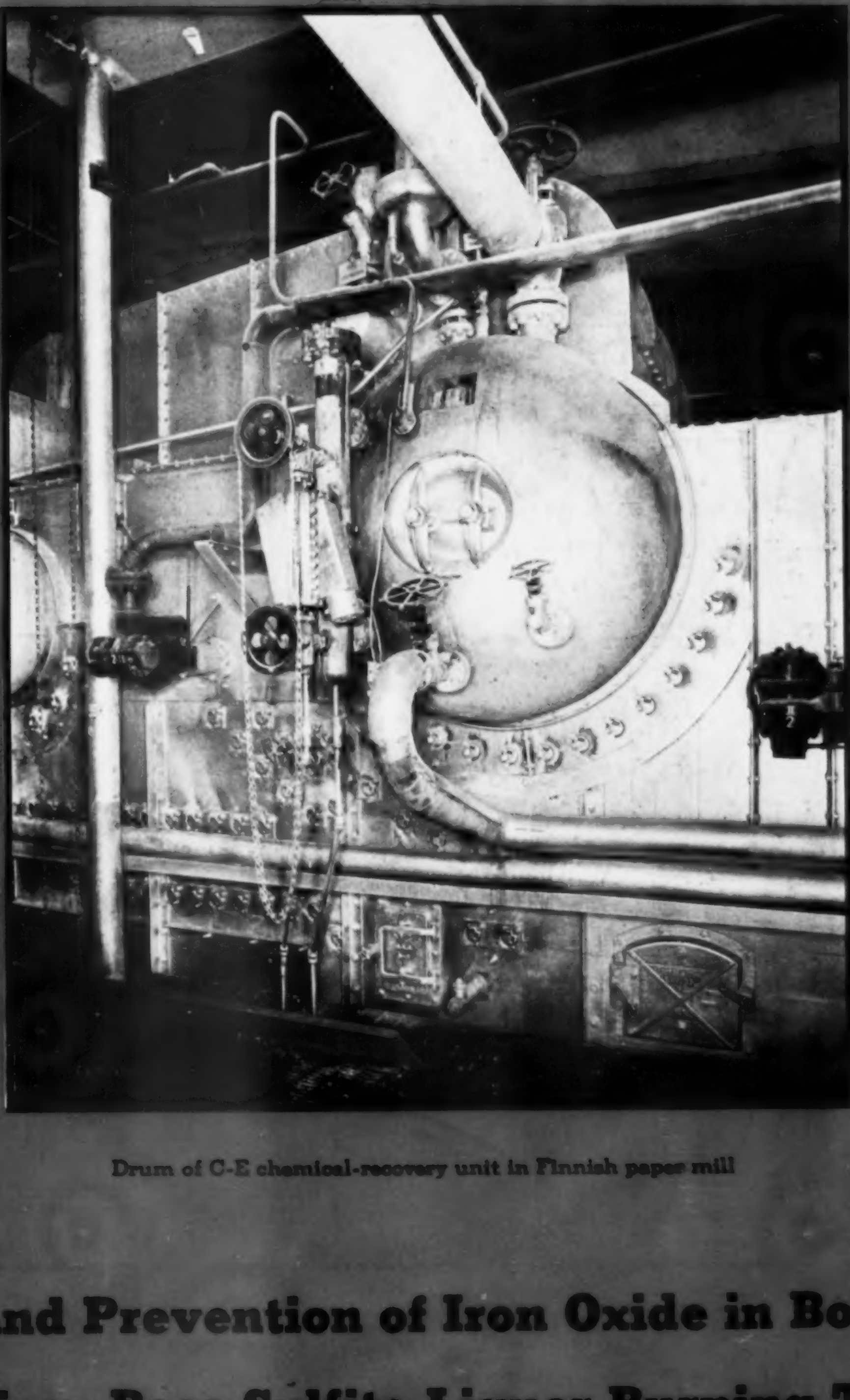
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

July, 1950



Drum of C-E chemical-recovery unit in Finnish paper mill

Causes and Prevention of Iron Oxide in Boilers

Calcium-Base Sulfite-Liquor Burning Tests

C-E REHEAT BOILERS

DUNKIRK STEAM STATION

Niagara Mohawk Power Corporation

The C-E Unit, shown here, is one of two duplicate steam generating units of the reheat type soon to go into service at the Dunkirk Steam Station of the Niagara Mohawk Power Corporation.

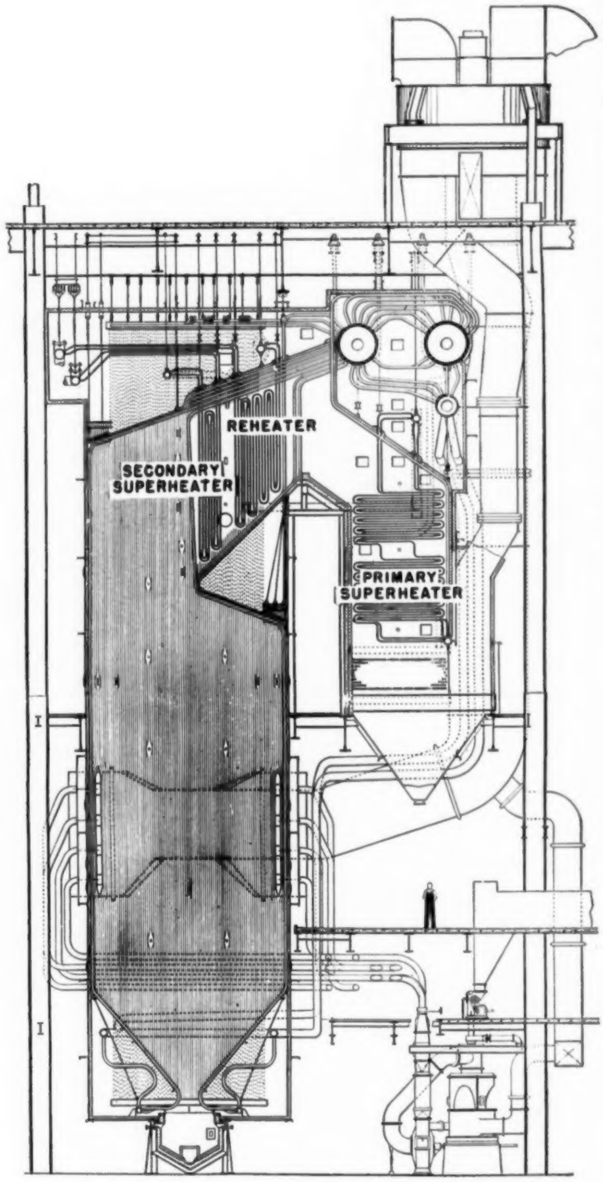
Each of these units will serve a 100,000 kw turbine generator operating at an initial steam pressure of 1450 psi and a temperature of 1000 F reheated to 1000 F.

The units are of the radiant type with a reheater section located between two stages of the primary superheater surface. A finned tube economizer is located below the rear superheater section, and regenerative air heaters follow the economizer surface.

The furnaces are fully water cooled, using closely spaced plain tubes throughout. They are of the basket-bottom type, discharging to sluicing ash hoppers.

Pulverized coal firing is employed, using bowl mills and vertically-adjustable, tangential burners.

B-385



C-E

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COMBUSTION

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Feature Articles

Editorials

Departments

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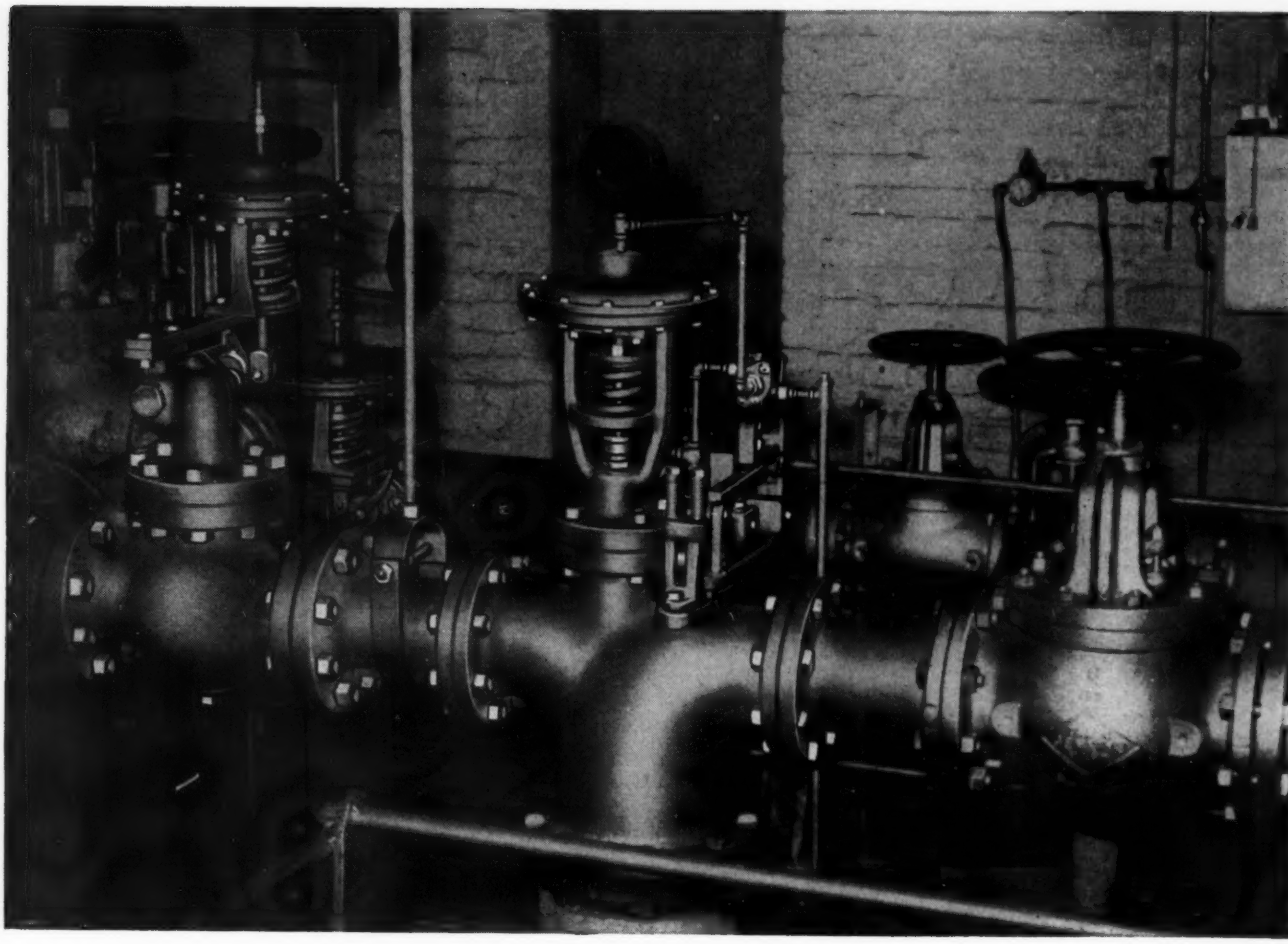

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COMBUSTION

Editorials

Another Decrease in Coal Rate

A late report by the Federal Power Commission shows that the average coal rate for electric utility power stations during May of this year was 1.18 pounds per kilowatt-hour. This figure is the lowest yet attained and compares with 1.22 pounds for May 1949. It reflects the performance of some five million kilowatts of new capacity that was added last year. As more and more old generating equipment is retired and the present ten million kilowatts of scheduled new capacity becomes operative in the next eighteen months or two years, one may look for a further substantial decrease in the average coal rate, especially as many of these plants will employ the reheat cycle with its attendant gain in efficiency.

The present figure is indeed a vast drop from the three pounds of thirty years ago and reflects much credit to power plant designers during the intervening period.

The New A.E.C. Chairman

It would be rather ridiculous to have an engineer whose education and training were limited to a narrow and specialized technical field appointed to the Supreme Court. And yet something quite analogous to this has just occurred in the appointment as chairman of the Atomic Energy Commission of a man whose background is closely tied to the legal profession by virtue of experience as an instructor in law, an attorney in the criminal division of the Department of Justice, and in charge of public relations at the Nuremberg trials.

The Atomic Energy Commission has a great diversity of responsibilities that may have a decisive effect upon the course of world events. Not the least of these duties is the one concerned with the maintenance of leadership in the technical development of atomic energy for both military and civilian uses. Without attempting to prejudge the case, it will be interesting to observe how effectively a person apparently lacking background in the industrial world as well as extensive training in either theoretical science or applied engineering can command the confidence essential for continued American preeminence in this highly important field. However, if the new chairman demonstrates that he can do this, he will be deserving of unstinted credit.

Mobile Testing Unit

Mention was made in these columns more than a year ago of an experiment undertaken by the British Ministry of Fuel and Power in an effort to raise the standard of performance among small industrial power plants. This was in the form of a mobile testing unit, consisting of a truck equipped with a complete line of instruments mounted on portable panels and manned by a competent crew. Service is free and the purpose is not only to promote fuel conservation through detection and correction of wasteful operation but also to educate the personnel in maintaining more efficient operation.

After a year's trial the results are reported in the British press to have been most satisfactory and extension of the service on a permanent basis is being considered.

The idea probably grew out of war experience in England when a voluntary organization within the Ministry of Fuel accomplished very substantial fuel savings through educational work among industrial power plants. In fact, it will be recalled that this served as a stimulus and a pattern for the National Fuel Efficiency Program set up in this country during the latter part of the war, although the war terminated before the full effect of the program could be appraised.

The mobile testing unit would appear to have possibilities in this country.

As Others See the Steam Power Plant

The privately owned, business-managed public utility companies have improved many aspects of public relations in recent years. Along this line one policy that deserves special commendation relates to the encouragement of power-plant inspection trips. Replacement of "No Admittance" signs that were formerly commonplace with friendly invitations to see at first hand how kilowatts are produced has brought many intangible returns of good will. But there have been direct returns as well, particularly in the case of security holders who have been so favorably impressed that they have increased their utility investments. Considering some of the anticipated difficulties in raising capital for public-utility expansion programs, this has indeed been a welcome by-product of the "open-house" policy.

Though the layman may not fully comprehend the thermodynamics of the regenerative cycle nor understand the distinction between kilovars and kilovolt-amperes, he can gain an understanding of the fundamentals of power production. And he can see for himself the complexity of equipment and operations for converting a lump of coal or a drop of oil into electric energy responsive to the flick of a switch. At the same time it might not be amiss to suggest that the objectivity of the visitors' fresh point of view may disclose things about the steam power plant that are not apparent to those for whom the novelty and the wonder have long since disappeared. There is still much to be said for the slogan, "See Yourself as Others See You."

President J. D. Cunningham addressing the Presidents Luncheon

A.S.M.E. Semi-Annual Meeting

ST. LOUIS, Mo., was the scene of the Semi-Annual Meeting of the American Society of Mechanical Engineers from June 19 to 23 with headquarters at the Hotel Statler. Although the attendance of about seven hundred was not up to that of some previous meetings, the program was diversified and the location afforded opportunity for interesting inspection trips, including a visit to the Venice Power Station of the Union Electric Company, the plant of the Midwest Piping & Supply Company, the Wagner Electric Company and the Synthetic Liquid Fuel Plant of the U. S. Bureau of Mines at Louisiana, Mo. The following report deals mostly with papers at the power, fuels and feedwater sessions.

The first technical session on Monday morning, held under the auspices of the Power and Fuels Divisions, comprised two comprehensive papers on fly-ash collection—one by means of the electrostatic precipitator and the other by means of the multi-cyclone collector.

Electrostatic Collection of Fly Ash

A review of the current status and trends of the electrostatic precipitation of fly ash was contained in a paper by **H. J. White, L. M. Roberts** and **C. W. Hedberg** of Research Corporation. They explained that the process is based on the fact that an electrically charged particle experiences a mechanical force when placed in an electric field, this force being proportional both to the charge on the particle and to the field acting on it. With the Cottrell these functions are performed in a single chamber by means of the high-voltage d-c corona discharge maintained between suitable electrodes (pipes and co-axial wires). The corona discharge supplies vast numbers of gas ions which far outnumber the dust particles and a high degree of particle charge is effected by attachment of gas ions to the suspended particles. A high collecting field is produced by the electric space charge set up by the large density of gas ions present between the discharge and collecting electrodes. Charging of the dust particles is accomplished in a few hundredths of a second.

The first electrostatic precipitator for power station fly ash was installed in 1923, shortly after the introduction of pulverized coal in the utility field, and since that time approximately 500 installations have been made in this country. Using the 1948 figure of 65 million tons of coal burned by utilities in pulverized form, and assuming an ash content of 10 per cent, this would correspond to over 6 million tons of fly ash that could be emitted annually if no means were taken to arrest it.

Fly ash is not homogeneous, and both its physical and chemical properties vary widely, depending upon such factors as type of coal burned, furnace operation and fineness of grinding. Its most important physical properties for electrical precipitation are particle size, particle density and bulk electrical resistivity. While the fraction below one micron is usually not important on a mass basis, a large fraction generally lies below 5 or 10 microns. In fact, some fly ash contains a substantial percentage of plus 44-micron (325-mesh) size. Particle shape is also heterogeneous and variable.

The bulk electrical resistivity is important for electrical precipitation. This has been found to be a function of gas temperature, gas humidity, and, most important, the presence or absence of extremely small amounts of SO_3 in the flue gas. Traces of SO_3 have been found adequate to maintain the bulk resistivity below the critical value of 2×10^{10} ohm-cm. The absolute amount involved generally corresponds to the conversion of something less than one per cent of the SO_2 content of the gases to SO_3.

Chemical analysis of fly-ash samples from some 60 utility plants showed the major constituents to be SiO_2, Al_2O_3, Fe_2O_3 and CaO, in addition to minor quantities of other elements.

With the present practice of installing the collector between the air heater and the induced-draft fan, stratification is not unusual with respect to temperature, water vapor, CO_2 content and gas velocity.

Efficiency of collection increases with area of the

collecting electrodes and decreases with increased gas flow rate. It is independent of particle concentration, but is dependent on particle size distribution. While large particles might be expected to be collected more effectively than fine particles, in practice it is found that the scouring action of the gas stream, particularly at high gas velocities, tends to erode or re-entrain some of the large particles from the collecting surfaces and thus reduce the collecting efficiency.

In precipitator operation the fly ash builds up gradually on the collecting plate surfaces and eventually forms compact layers which have a tendency to fall naturally but also usually require additional assistance in removal by "rapping." Discharge electrodes, on the other hand, are not ordinarily rapped as there is little tendency for dust to build up on the wires, except in a "combination unit" in which cyclonic collectors precede the electrostatic precipitator.

Although rapping is of utmost importance, when it is accomplished intermittently the stack clouding and puffs associated with it produce an objectionable psychological effect; hence closely controlled continuous rapping is more satisfactory.

The authors offered the following conclusions:

1. Although electrical precipitation has produced efficiencies of fly-ash removal exceeding 98 per cent, there remain complex problems inherent in its operation.

2. Promising means for combating non-uniform and variable conditions include low-intensity continuous rapping, automatic voltage control, the pulse method of energizing, combination collectors comprising centrifugal separators preceding the precipitators, and the conditioning of ash to maintain its resistivity below the critical value, by artificially increasing the SO_3 present. Centrifugal separators have a relatively high resistance to gas flow and, in combination with precipitators, are useful in establishing uniform gas flow. Also, they tend to level out stratification in ash content and ash composition.

Mechanical Dust Collectors

In his paper on mechanical dust collectors, **John T. Doyle,** vice president of The Thermix Corporation, recalled that prior to the last decade such collectors could be grouped into three categories, namely, settling chambers, cinder collecting fans or large-diameter cyclones, and baffle or impingement-type separators. In most cases installation was dictated by a local plant nuisance, product contamination, or because of fan erosion caused by large particles of fly ash in the stack gases. Such problems could then be met by a relatively inefficient collector when compared to present design standards.

Since that time public opinion has come to insist on improved atmospheric conditions and numerous more or less stringent ordinances have been enacted. This made it necessary for the manufacturers of dust-collecting equipment to step up their research programs in order to develop new designs that would meet the higher requirements.

While there were available multi-cyclone type collectors capable of approaching closely the highest efficiency now commercially obtainable by mechanical means, their size and weight were against their continued use. Hence attention was directed toward reduction in both space and weight. At first this led to some sacrifice in efficiency, but this has now been improved to a point that exceeds even the larger diameter multiple-cyclone unit, and at a cost considerably below the latter. It also became desirable to develop a unit having a more uniform total efficiency over a wider range of operation than was possible with the large diameter cyclone. The small multi-tubular collector lends itself to damper control.

However, in attempting to apply the knowledge gained through laboratory research and field installations, according to Mr. Doyle, the dust-collecting industry often runs into code requirements that are difficult, if not impossible, to surmount. The manufacturer may be requested to guarantee, without qualification, that the equipment will meet all requirements of the local ordinance. If this covers adapting the collector to existing fuel-burning equipment, it should be possible to predict with reasonable accuracy the efficiency to be expected; although it still must be qualified to meet variables in size and type of coal, percentage of ash, boiler rating and methods of operation. Field test work can do much to determine such conditions.

If the proposal covers application to a new installation, it is often difficult to guarantee the collecting efficiency without additional qualifications because of such variables as furnace design and conditions, turbulence, temperature and velocity of the gases ahead of the collector. This applies to both mechanical collectors and electrical precipitators.

For a dust-collecting engineer to prepare and submit a comprehensive proposal, he should be furnished with the following information:

1. Code compliance, plant nuisance or product contamination, and fan erosion
2. Sketch showing space available
3. Combustion data, such as pounds of steam per hour, pounds of gas per hour or cfm, temperature of entering gas, and plant altitude
4. Stack gas dust loadings in pounds per 1000 lb of gas, or grains per cubic foot
5. Analysis of dust or sample
6. Type of firing (if stoker, give kind and state whether reinjection is planned)
7. Type and source of coal
8. Available draft for collector
9. Evaluation, if any, of draft loss
10. Desired hopper storage capacity
11. Specific requirements, if any, for plate thickness, insulation, etc.

Any guarantee must of necessity be qualified and should be submitted in curve form, with dust size in microns plotted against per cent efficiency. With this curve submitted to the purchaser, it is possible for him to keep abreast of changing operating conditions.

Discussion

The question was raised as to whether in the combination arrangement the mechanical collector should be placed before or after the electrostatic precipitator, the case for the latter placement being that the mechanical collector is better able to handle the larger particles that are dislodged from the plates during rapping or

blowing. It was the consensus, however, that the better arrangement is for the mechanical collector to precede the electrostatic precipitator, especially if the rapping is continuous.

It was pointed out further by one discusser that the air-puff soot blower operating automatically in sequence offers advantages in keeping precipitator plates clean.

Another discusser cited British practice of employing very large electrostatic precipitators and low velocity gas. This, it was agreed, meant an expensive installation, although with sufficiently low velocity an electrostatic precipitator will collect most of the entrained solids both large and small.

As for collectors or precipitators and multiple fuels, it was pointed out that some oils have a tendency to form coke particles which have an oily film to which subsequent fly-ash particles will adhere and build up.

Smoke Meter Readings vs. Solids Content of Gas

Correlation between the opacity of flue gas, as measured by a photoelectric cell, and the actual weight of suspended solids, as determined by a filtration process, was reported in a paper by **W. F. Stoecker** of the Locomotive Development Committee. Tests indicated that the following factors must be considered in converting a photoelectric determination to a basis of weight per unit volume:

1. Temperature of the gases at the point where the photoelectric cell is installed.

2. Thickness of the column of gas. For a given smoke density, the light absorption by the smoke being measured must be converted to a light absorption value with some standard thickness of smoke column. Light absorption values of the standard column thickness must be calibrated against the smoke concentration expressed in weight per unit volume.

3. The percentage of ash in the solid particles. For a given smoke loading in the stack, the presence of fly ash causes a reduction in the light absorbed; and for precise measurements, each installation would have to be calibrated because of variations in fuel and methods of firing.

Microscopic examination of the smoke particles shows the size to be fairly uniform, but in the dense concentrations there is a greater tendency for the particles to form clusters. Furthermore, the increase in smoke density was accompanied by an almost linear increase in carbon monoxide concentration.

The work reported by Mr. Stoecker was performed in the Applied Research Laboratory of the Illinois Geological Survey.

Pressurized Furnaces

In a paper entitled "Knox Lee Power Plant's Pressurized Boiler—A New Trend in Steam Generation," **J. R. Welsh** of Southwestern Gas & Electric Co. and **L. Skog, Jr.**, of Sargent & Lundy, discussed special features in the design and construction of steam-generating units in which the furnace and boiler are operated under pressure without the aid of induced-draft fans. The plant is of semi-outdoor design and comprises two B. & W. gas-fired integral-furnace boilers of 300,000 lb per hr capacity operating at 875 psig and 910 F and two Westinghouse 30,000-kw Preferred Standard turbine-generator units. The objectives in employing a pressurized-furnace design include the following:

1. Increased steam-generator efficiency and reduced power requirements of draft equipment
2. Elimination of the I.D. fan and its control equipment
3. Elimination of breeching connection by relocating the stack at the air-heater outlet
4. Reduction of steam-generating-unit space requirements
5. A slight reduction in capital investment

At rated capacity the furnace was to operate at a pressure of approximately 8.3 in. water. The Sturtevant Axiflow forced-draft fans, under this condition, were to deliver 76,000 cfm at approximately 16.2 in. s.p. at 100 F.

An investment comparison indicated that the increased material and erection labor costs of the steam-generating units were more than offset by the savings resulting from the elimination of the I.D. fan, the reduction in the amount of required control equipment, and the simplification of the stack and duct arrangement.

The pressurized setting is said to increase boiler efficiency by 0.5 per cent by eliminating air infiltration and to reduce draft loss by approximately 15 per cent. By having the F.D. fan handle low-specific-volume, room-temperature air, the power required for draft purposes is approximately 20 to 30 per cent less. Maintenance and outage times of I.D. fans are also eliminated.

The authors concluded by citing the following points favorable to the use of pressurized furnaces for gas-and oil-fired steam-generating units:

1. Increased overall operating efficiencies
2. Reduction in equipment maintenance
3. Simplification of operation
4. Stabilization of combustion conditions
5. Reduction in auxiliary power

Discussion

Answers to a number of questions from the audience concerning experience with the pressure furnace developed (1) that there was an actual net saving of 94 hp in fan power through elimination of the induced-draft fan; (2) that the objectional noise of the forced-draft blower had been lessened by putting the air through a chamber equipped with baffles and having noise-deadening walls; (3) that with pressure firing the gases are progressively slowed down through the unit; (4) that soot blowers had been attached by means of a special arrangement that precludes leakage; and (5) that, in addition to the several pressure units now operating, nine more are under construction.

Cyclone-Fired Steam Generator

Merle Newkirk of The Dow Chemical Company delivered a paper entitled "A Cyclone-Fired, Pressurized Steam Generator" in which he told of the specific re-

quirements desired for this particular installation at the Midland plant of his company. Following a description of the apparatus used to achieve these results, the speaker described the unique features said to set this project apart from others; these included

- Higher boiler efficiency, due to (*a*) low excess air (10 per cent with a trace of smoke or CO at the furnace outlet); (*b*) a low percentage carbon loss in ash, (*c*) relatively clean absorption surfaces, and (*d*) low power consumption of auxiliary equipment
- Chemical cleaning of boiler
- Three-section air preheater
- Continuous operation on 100 per cent makeup with minimum blowdown
- Maximum continuous rating for given floor area, building volume, and total steam generator weight
- Elimination of induced draft

To date operation of the cyclone has been characterized by simplicity and safety, though some difficulties have been encountered by the inability to obtain continuous feed of coal to the unit. Because of the up and down firing brought about by numerous coal-feed interruptions, there have been some tube failures in the cyclone burner, where the heat release is on the order of 545,000 Btu per cu ft per hr. The speaker added that maintenance of ash fluidity at the cyclone burner tap is one of the most exacting of all operating considerations in the horizontal cyclone-firing method, for under the given temperature conditions with the volume of slag that must be handled the necessary mechanical requirements require a rather costly installation.

Coals burned in the unit had ash fusion temperatures ranging from 2200 to 2700 F, $2^1/_2$ to 15 per cent ash, 20 to 39 per cent volatile, and heating values of 8000 to 13,800 Btu per lb.

The author concluded with a description of the coal preparation plant and the reasons for its installation.

Discussion

Among the several inquiries following presentation of the paper was one asking why, if the cyclone takes most of the ash out of the coal, would it not be possible to increase the mass flow and employ closer spacing for the superheater tubes; another inquired as to the power consumption; a third as to the load range on individual cyclones; and a fourth as to whether oil could be burned.

The answers were that draft loss is a factor; that the power requirements for crushing are approximately one kilowatt-hour per ton; that individual cyclones have a load range of 2 to 1, and by employment of multicyclones a wider range of load can be accomplished for the unit; and that oil has been burned successfully in a cyclone.

Phosphoric Acid Cleaning of Boilers

Laboratory experiments followed by successful field use of inhibited phosphoric acid, as a substitute for the usual inhibited hydrochloric acid, for internally cleaning boilers were described in a paper by **T. E. Purcell** and **S. F. Whirl** of Duquesne Light Company, Pittsburgh.

The principal advantage of phosphoric acid, they pointed out, is that it can be boiled in the unit by direct firing of the boiler with negligible attack on the metal. The resulting natural circulation promotes distribution and provides a sufficiency of acid at desirable locations. This is in contrast to inhibited hydrochloric which can be used effectively only at temperatures below 150 to 165 F.

With hydrochloric acid, vapors escape from the solution and as the action of the inhibitor does not extend to the vapors, metal surfaces above the level of the cleaning solution are exposed to corrosive action. The vapors also pervade the plant atmosphere and are likely to attack other exposed equipment, as well as being toxic to plant personnel. By contrast, phosphoric acid is very stable in solution, even at temperatures above the boiling point.

Furthermore, since hydrochloric acid possesses no passivating or film-forming properties, after-rusting of the freshly cleaned metal surfaces is likely to occur. On the other hand, a 5 per cent inhibited phosphoric acid solution boiling at atmospheric pressure was found to give good deposit removal, negligible attack of metal and a surface resistant to rusting.

The authors then described the procedure as employed in washing a 600,000-lb-per-hr, 900-psig, 900-F boiler at their company's Frank R. Philips Station. This procedure was essentially as follows:

1. Alkaline boil-out at an average pressure of 244 psig for 24 hr using trisodium phosphate and sodium sulfite
2. Acid boil-out at atmospheric pressure for 8 hr, using inhibited phosphoric acid
3. Alkalizing and surface conditioning boil-out at an average pressure of 246 psig for 12 hr using tetrapotassium pyrophosphate, potassium hydroxide and potassium sulfite

Treated water and condensate were used for the boiling-out, and sheet-metal baffles were placed over the radiant superheater tubes to protect them from direct radiation of the oil fires. Also, all the regular safety valves were removed and a temporary safety valve set at 275 psig was installed.

To protect the superheater, condensate was admitted to the radiant superheater intermediate header to fill both the radiant and the convection superheaters.

The total cost of chemicals used in all operations was approximately $1500.

Chemical Removal of Copper From Boilers

The means employed in removing copper deposits from the tubes of a million-pound-per-hour, six-drum boiler at Logan Plant of the Appalachian Electric Power Company were discussed in a paper by **R. G. Call** and **W. L. Webb,** both of American Gas and Electric Service Corporation.

This unit, which went into service in November 1937, had been acid-washed three times, namely, in January

1948, March 1949 and January 1950, for the removal of predominently iron oxide deposits. Following the March 1949 washing with 5 per cent inhibited hydrochloric acid and a subsequent conditioning boil with a 0.25 per cent sodium chromate solution, selected wall tubes were turbined for removal of copper deposits. Shortly thereafter, the drums and lower headers were found to contain much dislodged sheet copper.

By November of that year it became apparent that the boiler again needed internal cleaning with a procedure that would also effectively remove the copper as well as the iron oxide. To this end experimental work indicated use of ammonium persulfate in the presence of ammonium hydroxide.

It was believed that the copper present was in the form of plating that occurred during the first acid cleaning and that a layer of iron oxide and copper had been deposited over it during subsequent washing. The following procedure was finally adopted:

The boiler was acid cleaned with 7.5 inhibited hydrochloric acid, the soaking period being 6 hr with the initial and final metal temperatures of 145–165 F and 135–155 F, respectively. The acid was then displaced with nitrogen, as were the two subsequent water rinses, during which the boiler temperature was held to 100 F maximum. The copper solvent was then pumped in over a period of about 4 hr at 85 F and allowed to soak for 30 min. During this time it was recirculated out of the top and into the bottom of the boiler. Draining time was $2^1/_2$ hr. The copper solvent and two subsequent rinses were displaced with compressed air. Samples of the copper solvent taken from the boiler during filling showed a range of copper concentration of 0.06 to 0.25 per cent with an average of 0.16 per cent.

The additional expense for copper removal, over that for acid cleaning only, was $3295, or about $11 per pound of copper taken into solution by the solvents.

Further research was recommended by the authors.

Discussion

It was pointed out that metallic copper alone is insoluble in hydrochloric acid, but in the presence of ferric oxide it is soluble; also that ammonia persulfate, which acts very quickly, must be handled carefully to prevent redeposition of copper. Other slower ammonium solvents were discussed. A soda ash reboil was recommended between acid cleaning and copper removal. Furthermore, under certain conditions the removal process may result in heavy accumulations of metallic copper in some areas that will later cause overheating.

Stressed was the importance of preventing incipient corrosion during the periods of fabrication, erection and putting a boiler in service.

High-Temperature-Equipment Safety Factors

A review of factors of safety and work-stress levels currently used in high-temperature equipment was made by **Ernest L. Robinson** of the General Electric Co. in a paper entitled "Safety Margins and Stress Levels in High-Temperature Equipment." For many years structures have been proportioned by using a so-called factor of safety related to the tensile strength of the material. More recently the development of complex elastic analysis and the perfection of analytic and mechanical means of determining maximum load stresses has resulted in relating safety factors to the elastic limit of the material. Since no question of safety is necessarily involved in exceeding the elastic limit because of a margin of ductility assuring local yielding, the real margin of safety may lie between the elastic limit and the tensile strength rather than between the design stress level and the elastic limit.

The proportioning of a structure to avoid elastic overstress may lead to an excellent design, but its reserves of safety may be out of proportion to the comparison of the ratio of its elastic properties to its working stresses. Thus elastic analysis is sometimes useful for proportioning but not so good as a criterion of safety.

Mr. Robinson had the following to say concerning the significance of formulas and their applications:

"It is important to note that actual stresses and temperatures must be used in carrying out any valid analysis rather than the artificial formulas used in recognized codes for assuring safety. Thus both the A.S.M.E. Boiler Code and the A.S.A. Code for Pressure Piping determine thickness by placing in a formula an allowable figure from a table. This practice adds one fixed slice to the thickness and one or more percentages, after which the next larger even schedule may be selected. A check back may show the actual stress to be only half or two-thirds the nominal figure, thus increasing the actual safety factor by these hidden margins. Engineers who are intimately familiar with the application of these formulas are likely to be cognizant of this matter. But such tables are widely quoted and in danger of being used by others not so well informed as to how and where the safety margins are secured. Constructive progress is only possible as a result of sound analysis, and sound analysis is very difficult except by the use of real stresses rather than nominal values. Predictions of service performance over the forthcoming years can only be based on test if the formulas correspond closely with reality."

Methods of creep determination vary from the simple constant stress test which approximates physical conditions in a turbine shell or boiler drum under steady pressure to the relaxation test at constant total elastic-plus-plastic extension that simulates bolt action.

With respect to ductility of materials intended for operation at high temperatures, the most important consideration is to facilitate manufacture and handling at ordinary temperatures. Manufacturing difficulties have been barriers to the progress toward materials suitable for high-temperature operation.

At times a condition of internal stress may be highly beneficial instead of detrimental. In localized areas, such as fillets, there would be a point of local overstress, without the aid of any internal stress, thereby giving fatigue a chance to start a crack. In such a region the existence of internal stresses in the form of a local surface compression, balanced by a larger central region of mild tension, can contribute to improve the notch fatigue stength, which is equivalent to a reduction in notch sensitivity.

In concluding Mr. Robinson expressed the belief that machines and equipment now being built and placed in service at temperatures for 900 to 1000 F and higher

have for the most part more adequate margins of safety relative to the strength of materials at operating temperatures than did similar equipment built twenty years ago before molybdenum and other alloy steels were in common use.

Oil From Shale

Boyd Guthrie and **L. W. Schramm** of the Bureau of Mines Oil Shale Demonstration Plant at Rifle, Colo., told the Fuels Session on Thursday morning that the cost of producing crude shale oil from 30-gallon-per-ton shale, using new mining and processing techniques, would be about $1.50 per barrel, exclusive of taxes and profits. This is about 50 cents lower than estimated by the Bureau a year ago. If present trends continue, they expressed the opinion that it would not be long until shale oil can supplement petroleum at comparable prices. It is estimated that about 300 billion barrels can be produced from a 500-ft thick measure of shale formation over a 1000-sq mile area in northwestern Colorado.

It has been demonstrated during production test runs that production rates of 148 tons per man-shift underground labor and 116 tons per man-shift total labor can be attained at a direct cost of 29.2 cents per ton.

Central-Station Gas Turbine

C. C. Willis of Oklahoma Gas & Electric Co. and **E. C. Goldsworth** of the General Electric Co., in a paper entitled "Engineering and Construction Problems Involved in the Huey Gas Turbine Installation," described some of the problems encountered in applying a 3500-kw, simple-cycle, locomotive-type gas turbine-generator unit to an existing electric utility steam plant.

At the end of World War II Huey Station had a total boiler capacity equivalent to 51,000 kw together with a combined turbine capability of 56,000 kw. Proposals to make up the deficiency in steam-generating capacity included the following:

1. Installation of an additional boiler
2. Steam supplied from external sources for feedwater heating
3. Feedwater heater separately fired by gas
4. Installation of a simple-cycle gas turbine operating on natural gas and equipped with an exhaust gas-recovery heat-exchanger for feedwater heating

Of the preceding propositions only the gas turbine provided a means of increasing both station heat rate and power output. Thus it was decided in February 1948 to purchase a locomotive-type gas-turbine unit of 3500-kw nominal rating. By incorporating an air precooler and a gas heat-exchanger for heating feedwater for the steam plant, this unit, according to studies, made possible a 7000-kw gain in plant capability, of which 4000 kw was due directly to the gas turbine-generator and 3000 kw to the release of extracted steam which could be used for power generation instead of feedwater heating.

Since the gas turbine was originally designed for railroad locomotive application, some changes and additions were required to adapt it to stationary utility operation. Instead of driving four direct-current generators through a reduction gear, the gas turbine at Huey Station drives an alternating-current generator through a single-reduction, double-helix reduction gear to which it is directly coupled. Starting is by means of a 250-hp wound-rotor induction motor which operates the gas turbine-generator up to approximately one-half speed.

Provision is made to have the unit shut down immediately in case of fuel failure, low lubricating oil pressure, and flame failure. A preliminary warning alarm followed by shutdown if the fault is not cleared, takes place under conditions of high exhaust temperature, high bearing temperature, and excessive vibration.

The gas turbine was shipped completely assembled and ready to be set on its foundation. The latter is relatively simple, only twelve foundation bolts being used for the gas turbine section of the installation.

Though the unit had never been run on natural gas before it was shipped from the factory, no difficulty was experienced in firing off at the first attempted start. Combustion has been very clean, and to date there has been no difficulty with the combustion system. Up to February 6, 1950, the gas turbine had operated 3912 hr and generated 15,486,000 kw with no unscheduled outages.

Gas Turbine Combustors

K. L. Rieke and **A. E. Hershey** of the Westinghouse Electric Corp. presented a paper on "Gas Turbine Combustors for Gaseous Fuels" in which they reviewed test and development work undertaken in modifying a 2000-hp experimental gas turbine for use as a booster unit in gas pipe-line pumping. When the fuel and oxygen are allowed to mix and burn more or less simultaneously in what is known as a diffusion flame, the combustion rate is determined by the rate of gas mixing. To obtain a pre-mixed flame, fuel and oxygen are mixed in varying proportions before entering the combustion zone, and the combustion rate is characteristic of the fuel, air-fuel ratio and the state of the combustible matter. For equal air-fuel ratios and rates of flow, the flame height of the diffusion flame is approximately ten times that of a pre-mixed gas flame. Accordingly, it would seem that space requirements for combustion would be much less if the fuel and air were mixed before they entered the combustion zone.

In evaluating the performance of any gas-turbine combustor, the following operating characteristics should be considered: completion of combustion, loss of total pressure, outlet temperature distribution, ease of ignition, flame stability, flame tube life, and carbon deposition.

Experimental tests of the combustor under discussion led to a design in which the unit may be converted from burning a liquid to a gaseous fuel by merely interchanging a set of fuel nozzles. While this change may be made in about an hour, a dual-fuel nozzle was also designed which makes possible a comparable change under operating conditions. The liquid-fuel nozzle uses an auxiliary fuel to get increased atomization, air normally

being used as the atomizing fluid, though gaseous fuel serves equally well.

Substantial confirmation of the combustion test results obtained in the laboratory has been obtained from actual operating performance of the gas-turbine booster unit. By providing correct fuel and air distribution in the combustion zone, both liquid and gaseous fuels may be burned satisfactorily in the same flame tube.

"Gas Turbine Combustors for Pulverized Coal" was the title of a progress report delivered by **Herbert R. Hazard** of Battelle Memorial Institute. To burn pulverized coal in a gas turbine, the operating conditions which must be maintained for satisfactory combustion include heat-release rates per unit of volume 50 to 100 times those common in boiler furnaces, variable static pressure ranging from 30 to 75 psia, and variable air-fuel proportions ranging from 6 to 20 times the stoichiometric ratio.

Regarding the turbine as a critical-flow nozzle, the volume rate of flow through the turbine is dependent upon the acoustic velocity at the nozzle throat, a quantity varying approximately with the square root of the absolute temperature at the turbine inlet. Since the turbine-inlet temperature is constant over the entire speed and pressure range of the turbine, volume rate of flow is approximately constant under turbine operation from one-third load to full load. The mass rate of air flow which varies directly with air density and volume flow rate is almost directly proportional to pressure. By an analysis of turbine operating conditions it can be shown that over the useful operating range the fuel rate and air rate are both almost directly proportional to static pressure.

In addition to the conditions just outlined, the pulverized-coal-fired gas-turbine combustor must fulfill the following important performance requirements: Combustion efficiency must be high, preferably above 95 per cent, both for fuel economy and to minimize ash-collector problems; pressure loss must be less than one pound at full load, or 1.5 per cent of static pressure; the temperature profile at the combustor outlet should be nearly flat; the structure must be durable; and the deposition of ash or slag must not prove troublesome during extended operating periods. In slightly different terms, the gas-turbine combustor is essentially a direct-fired air heater operating at a substantially constant air-fuel ratio except during periods of deceleration.

The combustor designed for the coal-burning tests consisted essentially of a burner which fired coal into a tube with approximately stoichiometric air for combustion, excess air being passed through an annular space between this tube and an outer shell to mix with the combustion products at the combustor outlet. During the experimental work the designs of the burner, the flame tube and the mixing zone were varied systematically in order to investigate quantitatively the effects upon combustor performance.

In summary Mr. Hazard stated that tests both at atmospheric pressure and at pressures up to 53 psia demonstrated that it is possible to obtain satisfactory performance with air-cooled combustors for burning pulverized coal in the gas turbine. One combustor was operated for over 300 hr at 53-psia pressure at the Locomotive Development Committee laboratory at Dunkirk, N. Y., and during this period of satisfactory operation ash deposition and distortion were negligible, while combustion efficiencies were better than those at atmospheric pressure.

Economic Stability

Speaking at the banquet, **Edwin G. Nourse,** nationally known economist and former chairman of the President's Council of Economic Advisers, warned that the economic stability of the country is threatened by a selfish struggle for monopolistic strength among labor, agriculture and capital. Each group has pursued its own immediate advantage without regard to the wider repercussions on the national economy. Moreover, if voluntary administration of our industrial processes is to proceed on lines of peace and efficiency, such as to promote stabilized prosperity, the concept of economic solidarity must be mastered.

In this connection, Mr. Nourse added that agriculture, after making a promising start toward defining its rôle, had progressively redefined parity to make it less and less a formula for economic adjustment of production and more and more a cloak for Federal subsidy to farmers politically shielded from the need for constructive adjustment. Also, labor, despite impressive declarations, has not been willing to rely upon bilateral collective bargaining in good faith and has used its mass power to exact unilateral decisions. Management has often been equally obdurate in clinging to past traditions or future aspirations.

"Government planners," said Mr. Nourse, "have been willing to follow reformist dogma to the point of making operative conditions difficult if not impossible for private business; and reactionary business men, while clamoring for reduction in government spending, have put on political pressure to get themselves exempted from any act that adversely touches their company or their community.

"Among our people the 'gimme' spirit is rampant and the demand for personal security is put above the old spirit of personal creative achievement. Political agrarianism and political laborism have forged ahead of political capitalism of the past, and the merger of farmer and laborer into an unbeatable coalition seems to be the pattern to which we are being adroitly led today," he concluded.

Nominations

The Nominating Committee reported the following nominations for 1951 officers, which will be voted upon in the fall by letter ballot:

President: **J. Calvin Brown** of Los Angeles, engineer and attorney specializing in patent, trademark and copyright litigation.

Regional vice presidents: **Henry R. Kessler,** Republic Flow Meters Co., New York; **Stephen D. Moxley,** American Cast Iron Pipe Co., Birmingham, Ala.; **Dr. J. T. Rettaliata,** Illinois Institute of Technology, Chicago; **Prof. C. J. Eckhardt,** University of Texas, Austin, Tex.

Directors-at-Large: **Lionel J. Cucullu,** New Orleans Public Service, Inc., New Orleans; **Harold E. Martin,** Babcock & Wilcox Co., New York.

Side Branch Tubes in Water Walls*

This arrangement for water walls employs a main tube and two small-diameter welded-on branch tubes spaced on relatively wide centers. It was devised to overcome the header disadvantages of large-diameter, closely spaced tubes and as a substitute for finned or bifurcated tubes. First used some years ago at Västerås power station, it has since been applied to many other units in Sweden. Circulation is discussed and experience with this design is reported.

By THORSTEN WIDELL
Stockholm, Sweden

THERE are several types of vertical water walls. Large-diameter, relatively thick-walled, plain tubes closely spaced, as indicated at *a*, Fig. 1, are widely used but they require increased header dimensions or use of a double header. Such tubes contain a large amount of water, which results in higher losses during the initial period and a longer starting time. This may be disadvantageous for boilers requiring intermittent operation. It can generally be said that the proportion of water volume in the boiler below the drum should be as small as possible.

Various designs have been employed to avoid disadvantages with closely spaced tubes, such as fin tubes, as indicated at *b*, Fig. 1, which consist of ordinary tubes with metal fins welded on to the sides. Another design, Fig.

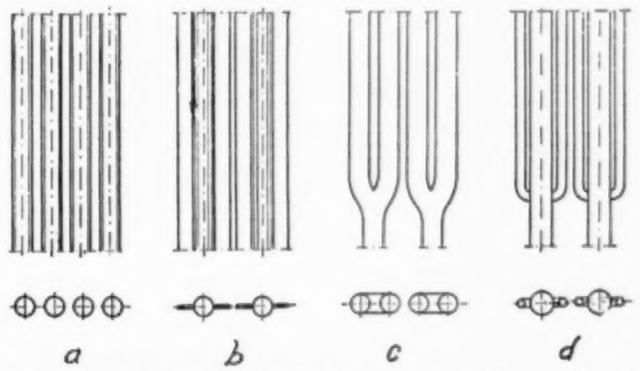

Fig. 1—Tube arrangements for water walls—*a*, closely spaced large plain tubes; *b*, fin tubes; *c*, bifurcated tubes; *d*, side branch tubes

1(*c*), consists of bifurcated tubes arranged so that two tubes of the same diameter are joined into a single larger tube just over the header. Still another arrangement consists of a main tube with two tubes of smaller diameter welded to the main tube, as indicated by Fig. 1(*d*).

The last-mentioned arrangement was first employed by U. Blomquist at the Västerås Power Station following difficulties with the cracking and burning of fins. It was adopted after tests with the model shown in Fig. 2.

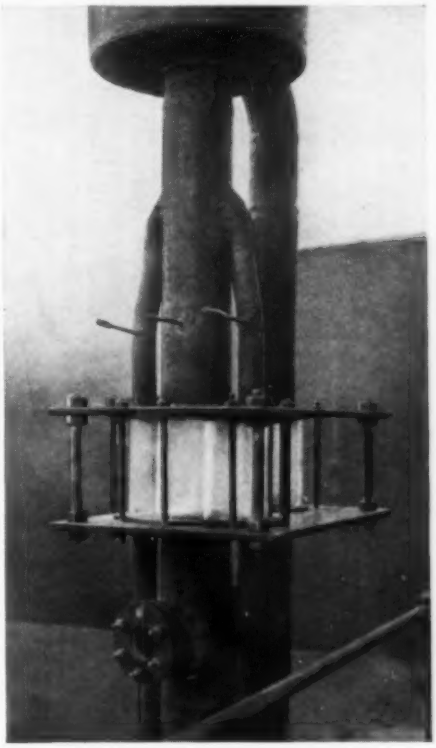

Fig. 2—Apparatus for investigating circulation in branch tubes

Spacing of the main tubes is not too close so that rolling into the headers can be carried out without difficulty. Their reliability depends upon the circulation both in the main tubes and in the side-branch tubes. It might seem that the main tube could act to short-circuit the branch tubes thereby depriving them of their share of the water. As a matter of fact, however, steam production in the small branch tubes has been found to be greater than in the larger main tube. For example, calculations show that a tube system consisting of a 102-mm main tube and two side-branch tubes generates 62 per cent of the steam in the main tube and 19 per cent in each side branch. This applies to 200 mm distance between main tubes. As a side-branch tube has only 9.15 per cent of the total area, the steam produced in it, in proportion to its cross-section, is about $2^1/_2$ times as great as in a main

* Translated and abstracted from *Teknisk Tidskrift* by István Juhász, consulting engineer, Stockholm, Sweden.

tube. Furthermore, although the side tubes have greater pressure loss, the entrance velocity is much greater than in the main tube. Calculations for a 65,000-lb per hr unit showed a circulation ratio of about 23 for the side tubes.

Fig. 3 shows part of the water wall with side-branch tubes installed in the furnace of a later unit at Västerås Station.

Experience with these side-branch tubes is claimed to be very good and no wall tube damage has been reported with this arrangement. In fact, on the first boiler so equipped at Västerås in 1937, no wall tube trouble has since occurred and equally good results have been obtained with later boilers at this and other plants equipped with this type of tubes. Moreover, application of side branch tubes have made it possible to increase the rate of steam release. This at first resulted in priming which was overcome by the installation of "foam caps" placed over the ends of tube extensions above the water line in the drum, as indicated in Fig. 4. The effect of these foam caps is partly to alter the direction of the mixture; further to act upon the steam-water mixture as a separator; and also to provide a slight choking effect which prevents too intensive circulation through single tubes.

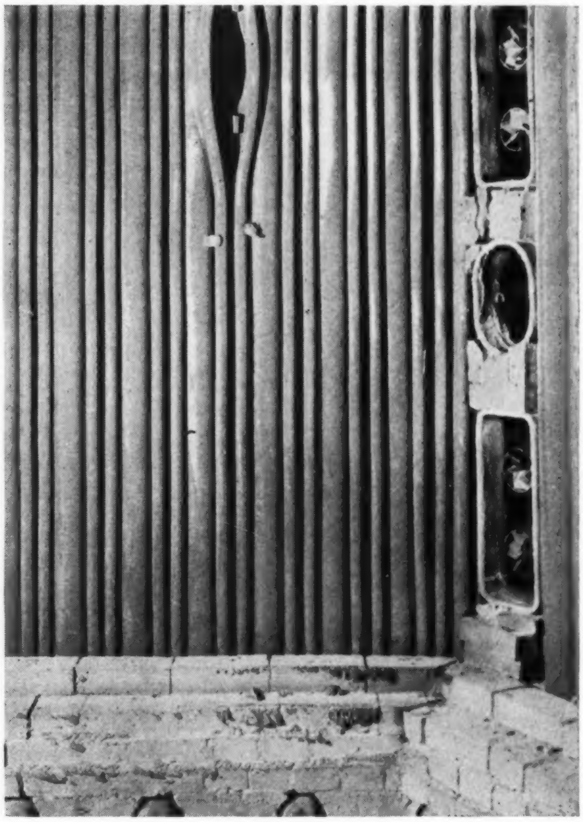

Fig. 3—Furnace wall tubes of side-branch type in a unit at the Västerås power station

Fig. 5 shows a cross-section of a steam-generating unit of 100,000-lb per hr rated capacity equipped with branch tube water walls. This unit is intended to be fired with pulverized coal, but also has a small chain grate stoker, the dual purpose of which is to remove the ash and serve to insure ignition with low-volatile coal. The unit has an economizer, a fly-ash precipitator and two Ljungstrom air preheaters. Air and flue-gas ventilators are placed over the air preheater.

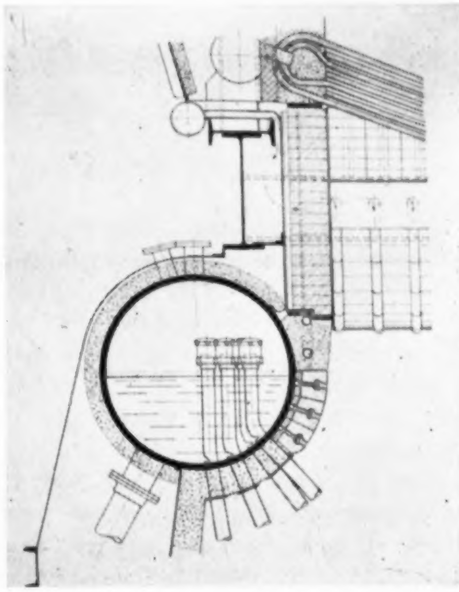

Fig. 4—Arrangement with foam caps on tube extensions in drum

As regards cost, a water wall with side-branch tubes is said to have an advantage over a wall with closely spaced ordinary tubes, particularly for higher pressures. In the case of walls with all welded tubes, the difference in cost is not great. The total weight of the water volume is, however, less in the case of side-branch tubes. The smaller volume of water is also advantageous from the point of view of intermittent operation.

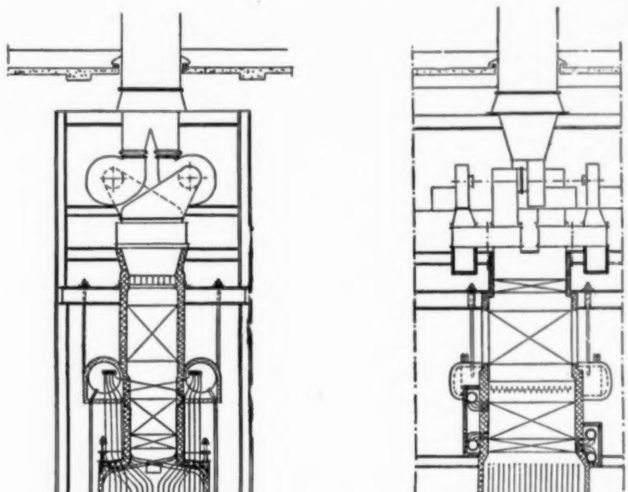

Fig. 5—Cross-section of 100,000-lb per hr, 425-psi boiler with side-branch tubes and equipped with small traveling grate stoker for ash removal and to sustain ignition with low-volatile coal

*Causes and Prevention of Iron Oxide in Boilers**

By S. T. POWELL, L. G. VON LOSSBERG and J. K. RUMMEL

Consulting Chemical Engineers, Baltimore, Md.

Protection of boilers against corrosion by iron oxide has become an important consideration in central station operation. This article enumerates and analyzes sources of iron oxide and suggests corrective measures which may be taken to forestall corrosive conditions. As far as possible, the principal sources of iron oxide in boilers have been related to their respective causes of corrosion. Means are also discussed for minimizing corrosion in cases where it is not practical to eliminate completely its source.

IRON oxides compose an appreciable part of the deposits found in boilers subjected to a wide range of operating conditions. These oxides are often masked by calcium and magnesium compounds. This is true especially where the percentage of feedwater makeup is high. However, deposits of this kind occur also in boilers in many central stations and in industrial plants when the makeup requirements are low and where feedwater of good quality is used.

Iron oxides and other metallic deposits present serious operating problems and necessitate frequent boiler outages for cleaning. Neglect may lead to tube failures. The quantity of metallic oxides present is related closely to the corrosion and corrosion-erosion activity in the boiler-steam-feedwater system. The rate of iron oxide production throughout the steam-water cycle, as well as within the boiler, is influenced by the composition and physical characteristics of the metal, the design of the equipment, operating conditions and many other pertinent factors.

The secondary problems presented by the presence of metallic oxides suspended in the water or entrained in the steam are frequently more troublesome than the actual damage due to corrosion.

Nature and Concentration of Iron Oxides in Boilers

The iron which is carried into a boiler may be in various forms both with regard to its chemical composition and physical state. Many of the iron compounds found in boilers are present as insoluble oxides. They may be divided roughly into two types, namely, red iron oxide, Fe_2O_3 and black magnetic oxides, Fe_3O_4. The red oxide (hematite) is formed under oxidizing conditions, which produce this stable compound (Fe_2O_3). The black oxides (magnetite and wüstite) are formed when oxidization cannot go to completion. Mill scale is a typical example of the latter form.

The bulk of the red iron oxide is reduced to the black iron oxide at the temperature and reducing enviornment prevalent within the boiler under steaming conditions. However, it is well established that the several iron oxides can co-exist.

Alquist (1) has reported many analyses of deposits from boilers located in various parts of the United States. He has shown that iron oxide produced within boilers is most likely to be in the form of magnetite (Fe_3O_4). Further, with the exception of corrosion products formed and retained in place on the boiler metal, it is not possible to distinguish between the iron oxide produced external to boilers and that produced internally. However, it is possible to evaluate by an adequate survey the total amount of iron compounds entering the boiler with the feedwater and those created within the steam generating unit.

In general, iron oxides which are circulated with the boiler water and not removed by blowing down settle out as slightly adherent coatings of finely divided material on the boiler tubes or as a mixture of coarse and fine deposits in areas of less rapid circulation. In cases where the deposits are voluminous and permitted to form a hard dense adherent scale, they are likely to cause overheating of the metal. This condition encourages still further production in iron oxide. Such deposits may be present in boilers which have undergone corrosive attacks of severe nature. This type of corrosion is frequently accompanied by embrittlement of the metal. The corrosion-embrittlement attack, which has been noted in a number of high-pressure boilers, has been described at length by Boetcher (2), Powell and von Lossberg (3), Straub (4), Brister and Romer (5) and Partridge and Hall (6).

TABLE 1—IRON AND COPPER IN MAIN CONDENSER CONDENSATES HAVING pH VALUES BELOW AND ABOVE pH 8

Boiler pressure 1050 psig—Steam temperature 915 F—Evaporated make-up water

Number of Tests Unit A	Number of Tests Unit B	pH Value of Steam Condensate	Iron in Ppm Average Unit A	Iron in Ppm Average Unit B	Copper in Ppm Average Unit A	Copper in Ppm Average Unit B
30	34	6.5 to 7	0.155	0.10	0.036	0.026
47	61	7.9 to 8.4	0.072	0.08	0.023	0.023

Experience at a number of power stations by the authors and others have demonstrated that excessive corrosion has occurred in boilers due to the presence of iron oxide either alone or accompanied by copper. The data presented in Table 1 and Figs. 1 and 2 are typical of the rate of iron and copper production in a central station equipped with boilers operated at 1050 psig and delivering steam at a temperature of 915 F. Alexander and Rummel (7) reported their findings of studies at this

* A paper presented at the 1950 Midwest Power Conference.

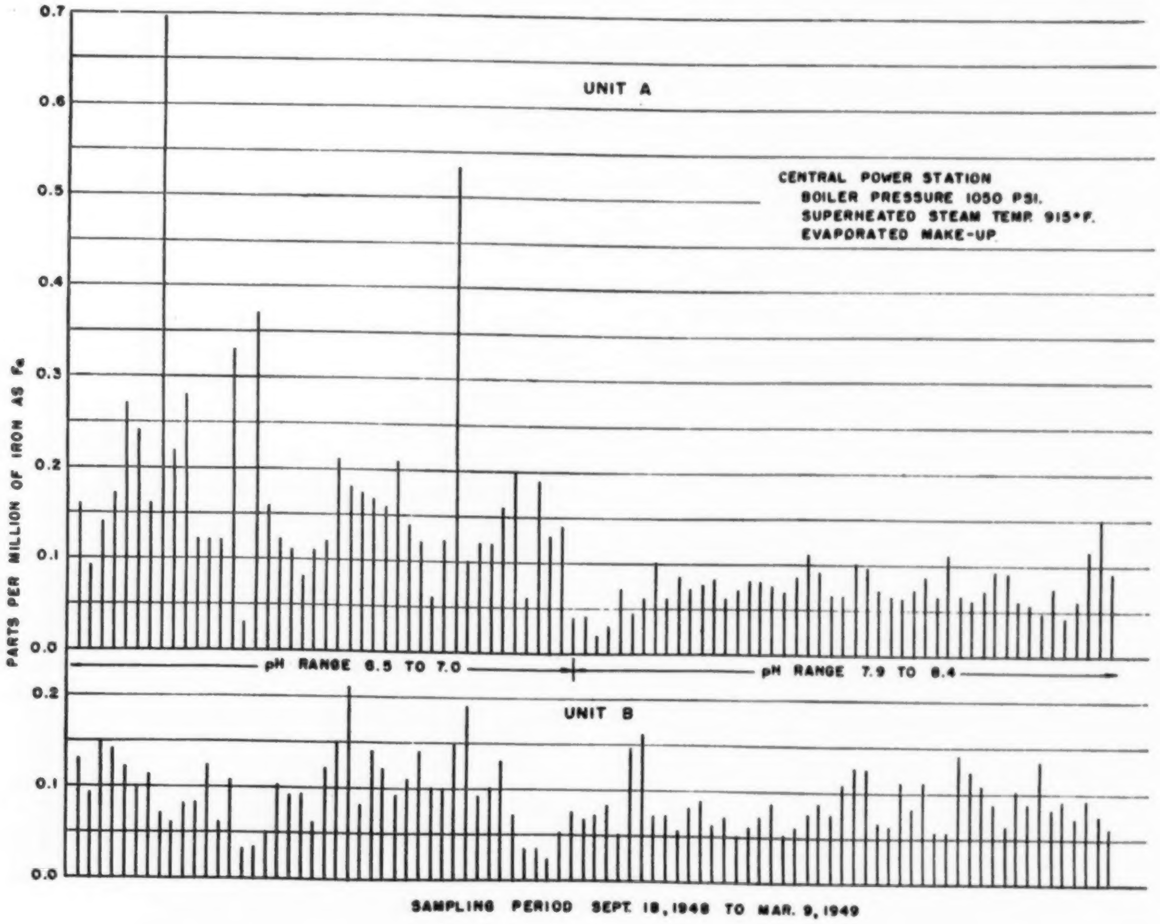

Fig. 1—Iron in condensate samples from main condenser hot well pumps

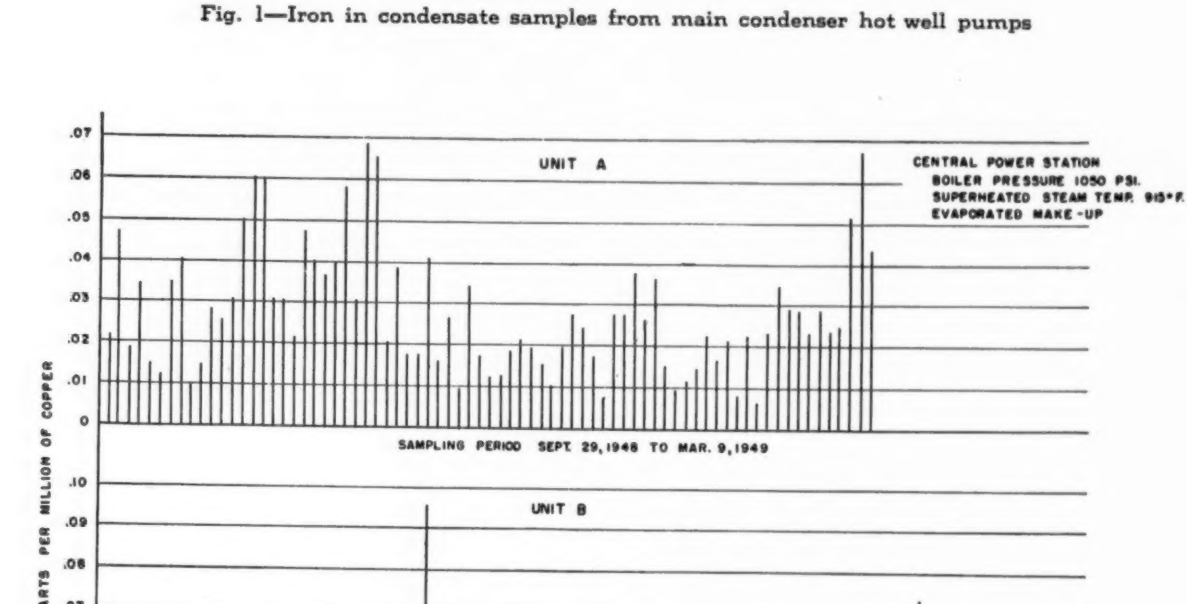

Fig. 2—Copper in condensate samples from main condenser hotwell pumps

station at an earlier date and showed that 0.10 ppm of iron and 0.03 ppm of copper were present in the feedwater. There was considerable variation in the amount of iron found in the samples of water withdrawn from any given point in the feedwater system and no progressive increase in iron or copper was observed as the water passed from the condenser hotwell to the economizer. The variations in iron content were believed to be due largely to the intermittent deposition and re-entrainment of iron oxide in the water and, in some degree, to the changes in the rates of corrosion and erosion of the metals in the system. This assumption was verified by the occurrence of a relatively large amount of iron oxide in the samples which were taken when there was a considerable change in load on the unit.

There was a sharp drop in the average iron and copper content found in the condensate samples from the hot well of one unit after the pH value was increased from approximately 6.5 to 8, or slightly above. The iron content of the combined drips from the stage heaters and evaporator condenser was similar to that found in the condensate from the hot well but the copper content averaged 0.042 ppm, which was 0.006 ppm to 0.019 ppm higher than in the hot well condensate. This condition was due to the higher dissolved gas content (including NH_3) of the drips from the heaters and evaporator condenser.

At a second station, where the boilers operated at 900 psig and where the superheated steam temperature was 915 F., the iron content of the condensate from the hot well and the feedwater to the boiler feed pumps varied between 0.01 and 0.06 ppm. The iron in the condensate from the evaporator during the same period was as high as 0.14 ppm to 0.19 ppm. The copper content of the feedwater varied between 0.01 ppm and 0.05 ppm despite the fact that there was not more than 0.01 ppm of ammonia in the steam at any time. These concentrations are typical of many stations but cognizance of the condition and its importance is not always realized.

During the study referred to, the magnitude of the results obtained by analyses of spot samples was checked by passing a continuous sample of water through a small supercentrifuge for periods varying from several days to a week; the composite samples of the insoluble residue thus collected were weighed in the laboratory. Some samples were completely analyzed. However, the insoluble nature of the iron was shown by the constant low residual iron content of the water leaving the centrifuge. Studies of this type are justified where iron oxide deposits are a real or potential source of difficulty. In this particular instance the data compiled indicated corrective measures required.

Data relating to the amounts of iron and copper in the feedwater for a boiler operated at 2000 psig, were shown by Bissell, Cross and White (8) who reported, also, on the quantity of iron entering and leaving the boiler. The amounts of iron found in the feedwater were similar in magnitude to those just reported. The quantities of copper in the feedwater, as reported by Bissell, Cross and White, were lower despite the higher concentration of ammonia in the steam. This may have been due to a difference in analytical procedures.

Usually the erosive-corrosive action upon boiler feed pumps and regulating valves is not a large contributor to the total iron and other metals in the feedwater but it is of sufficient importance to require attention during a plant survey. Wagner, Decker and Marsh (9) have reported on a series of tests which show, under controlled conditions, the rates of attack on various metals used for fabricating such equipment; chrome-steel alloys were found to be the most desirable.

It has been established that the presence of appreciable amounts of iron oxide in steam boilers is not a direct proof that any unusual attack upon the boiler metal is occurring. Many low- as well as high-pressure boilers have operated safely for years regardless of the continued presence of significant amounts of iron oxide sludge. Nevertheless, such deposits are a potential source of trouble and should be removed before the accumulations become excessive. When the rate of deposition of iron oxide is rapid, unscheduled boiler outages become necessary. If the oxide is not removed it may become adherent and cause overheating and corrosion; see Fig. 3.

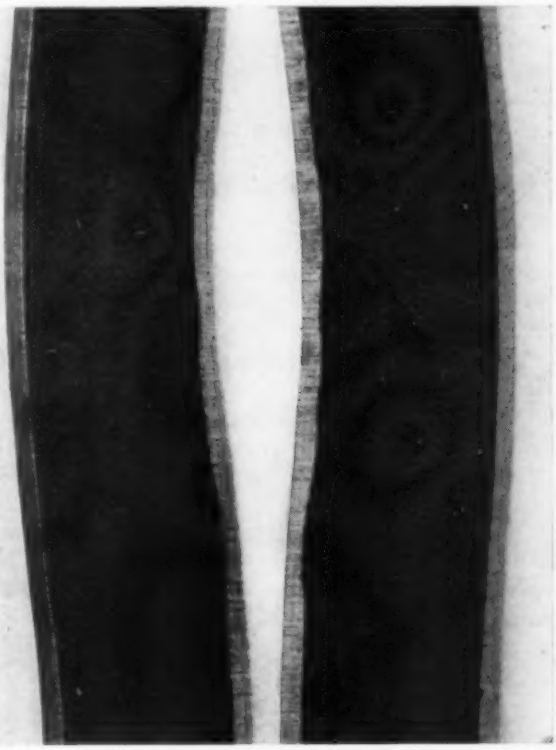

Fig. 3—Corrosion attack of boiler tube induced by overlying deposits in absence of hydroxide alkalinity

Program for Investigating Iron Oxide

The prevention of diminution of corrosive reactions which produce iron oxide within the boilers can be accomplished in several ways. Before the problem can be controlled it is necessary, first, to determine the source of the deposits. A survey of conditions to ascertain how and why the deposits are created should include the following items:

1. The determination of the approximate rate at which iron oxide is being formed. This should include measurements of dissolved oxygen and hydrogen in the feedwater, measurement of hydrogen in the steam and the determination of iron oxide entering and leaving the boilers and superheaters. The boiler sludge should be analyzed to establish the percentage of metallic oxides present.

2. Inspection of the boiler should be made for visible

signs of corrosive attack. Reports pertaining to the quantity, quality and location of the deposits should be correlated.

3. Analyses of the feedwater and boiler water should be made for the determination of dissolved gases, pH value, alkalinities, sodium sulfite, dissolved iron, suspended iron oxide and copper.

4. A metallurgical examination of damaged or failed metal should be made to establish the specific type of attack.

Sources of Iron Oxide

Iron compounds accumulate in boilers from so many causes, that their source, or sources, is detectable only by a comprehensive investigation. The major causes of these deposits are listed herewith:

1. Accumulation of mill scale from equipment containing such formations from the time of its original installation.
2. Corrosion during the irregular starting-up period for new equipment.
3. Corrosion resulting from idle period during which the protection was inadequate.
4. Products of electrochemical corrosion promoted by dissolved gases, dissimilar materials, localized metal stresses and low pH of the water in contact with the metal.
5. Erosive action of the water and steam occurring at points of high velocity.
6. Corrosion products caused by high temperature iron-water and iron-steam reactions induced by localized overheating of the metal, either in superheater tubes or in the boiler.
7. Thermal shock resulting from rapid chilling of metal; under some conditions this action has been responsible for stress-corrosion attack resulting in the formation of black oxide.
8. Products of corrosion caused by stray currents or the grounding of electrical equipment to the feedwater system or to the boiler and related structures.

Since the causes and correction of the iron oxide problems differ depending on a number of factors internal and external to boilers, the problem is discussed as follows:

1. Corrosion of metallic surfaces external to boilers.
2. Corrosion within the boiler and superheater.

External Corrosion

It is inevitable that considerable iron, as well as other metals, will be picked up from the piping, valves, pumps, tanks and other accessories external to a boiler.

This matter has been discussed by Donworth (10) who has shown the relative areas of ferrous and nonferrous metals in contact with steam and water in a typical regenerative cycle. The author drew attention to the erosion of turbine blades, casings and condenser casings in the path of the steam and water mixture, the corrosive and erosive action of water on boiler feed pumps and the considerable solvent power of water on all the materials in the system.

Other investigators (*11*), (*12*), (*13*) have discussed the general and specific mechanisms of electrochemical corrosion of metals and the matter of passivating the surface or creating protective films which will act as barriers between the metal and the corrosive medium. It has been agreed generally that a thin barrier of iron oxide on the metal surfaces is the main reason why a larger amount of iron is not present in most water systems constructed of iron and steel. Unfortunately, practical conditions of operation do not always lend themselves to the establishment of a permanent stable film at all locations through the system. During operation, the metal surfaces are subject to change which damage the surface coatings and this accelerates the rate

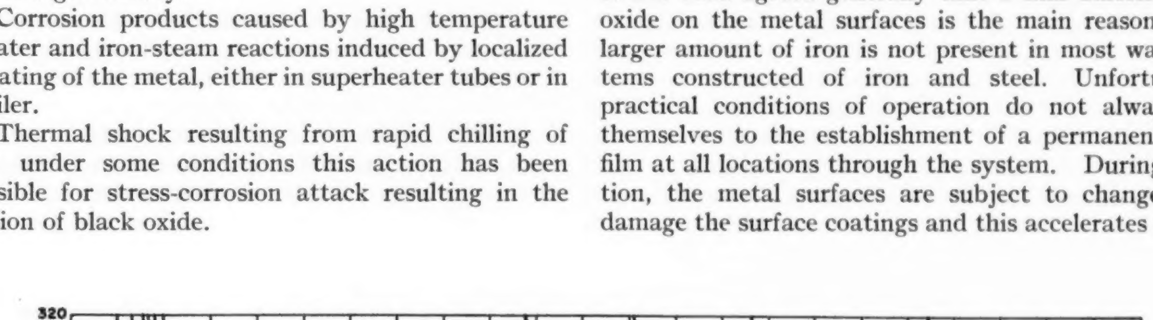

Fig. 4—Calculated effect of CO_2, temperature and alkalinity in steam on the pH value in condensate drips

of corrosion. Erosive action is especially aggressive to protective films or coatings. Here again when the protective films are broken or destroyed the rate of corrosion is greatly accelerated.

The part played by dissolved oxygen in promoting continuous corrosion is so generally understood that it needs no discussion here. Obviously, effective deaeration should be provided as early as possible in the cycle.

Effect of Carbon Dioxide

Carbon dioxide is one of the principal gases causing an aggressive attack upon the steam lines, condensate piping and related appurtenances The concentration of this gas, wherever the dew point is reached, is an important factor in the aggressiveness of the condensate formed.

It has been found that the corrosion in steam piping at points where drips are formed is not as severe as that in pipes which the condensate is carried. This is true even when the CO_2 concentration in the steam is the same as that in the condensate. This is due to the fact that the CO_2 which dissolves in the condensate drips in contact with the steam reaches equilibrium with the entrained gas, and this equilibrium is a function of the partial pressure of the total gas present; at equilibrium only a percentage of the total CO_2 dissolves in the liquid phase. When the entire steam supply is condensed, the total quantity of CO_2 present dissolves in the liquid phase; thus the reduction in pH of the condensate formed is more pronounced. Fig. 4 shows the calculated pH value of pure condensate in contact with steam (such as drips formed in the steam line) under various temperatures and with different concentrations of total entrained CO_2.

Practical control of corrosion due to CO_2 in the steam lines (in the absence of oxygen) requires keeping the total concentration of this gas as low as possible.

The combined corrosive effect of dissolved oxygen and CO_2 is more severe than the presence of either gas alone in the same respective concentration. It has been generally established that the CO_2 is more damaging to condensate collecting systems than the traces of oxygen usually found.

TABLE 2—DECOMPOSITION OF BICARBONATES IN BOILER FEEDWATER BY DEAERATING HEATERS* HCO_3, CO_3 AND CO_2 EXPRESSED IN PPM OF EQUIVALENT $CaCO_3$

	Heater Influent			Heater Effluent					
Plant	pH	HCO_3	Free CO_2	pH	HCO_3	CO_3	CO_2 from Decomposition	Total† CO_2 vented from heater	Percentage of HCO_3 in influent to heater converted into CO_2 by heater
1	6.0	23.8	33	8.8	12.3	6.0	5.5	38.5	23.0%
2	5.9	22.0	36	8.7	10.6	6.0	5.4	41.4	24.6%
3	6.0	24.6	32	8.7	13.2	6.0	5.4	37.4	22.0%
4	6.0	25.2	34	8.7	17.2	4.0	4.0	38.0	11.8%
5	6.0	25.2	34	8.7	9.8	8.0	7.4	41.4	21.8%
6	6.2	22.0	20	8.7	8.2	4.0	9.8	29.8	49.0%
7	6.2	22.0	30	8.7	13.2	6.0	2.8	32.8	9.4%
8	6.1	23.0	31	8.7	11.5	6.0	5.5	36.5	17.7%
9	6.2	26.2	32	8.7	18.0	4.0	4.2	36.2	13.2%

* Calculations from data by Cochrane Corp., heaters of atomizing type.
† Free CO_2 + CO_2 from decomposition of HCO_3 in feedwater.

It was demonstrated by J. H. Walker (14) that the rate of corrosion of pipe lines carrying condensate containing dissolved CO_2 is a function of the velocity flow as well as the concentration of CO_2 present. Walker found that when the rate of flow was taken into consideration by plotting the product of the CO_2 concentration and the velocity that this product could be correlated with the rate of penetration of the metal.

The influence of carbon dioxide on the corrosion rate in condensate collecting systems is most critical in plants where high makeup containing bicarbonates and carbonates is required. Considerable data have been compiled to show the percentage of decomposition of bicarbonates in passing through deaerating heaters, as well as the degree of decomposition of carbonates and bicarbonates under steaming conditions in the boilers. Because of the value of this information in calculating or estimating the CO_2 in the steam or condensate, these data are being presented herewith.

Table 2, representing actual tests taken from nine different plants, shows the quantity of bicarbonates converted to carbonates in passing through deaerating heaters; the CO_2 resulting from this decomposition is driven off with the vented steam. An average of 21 per cent of the bicarbonates in the water to the deaerating heaters was decomposed in passing through the units.

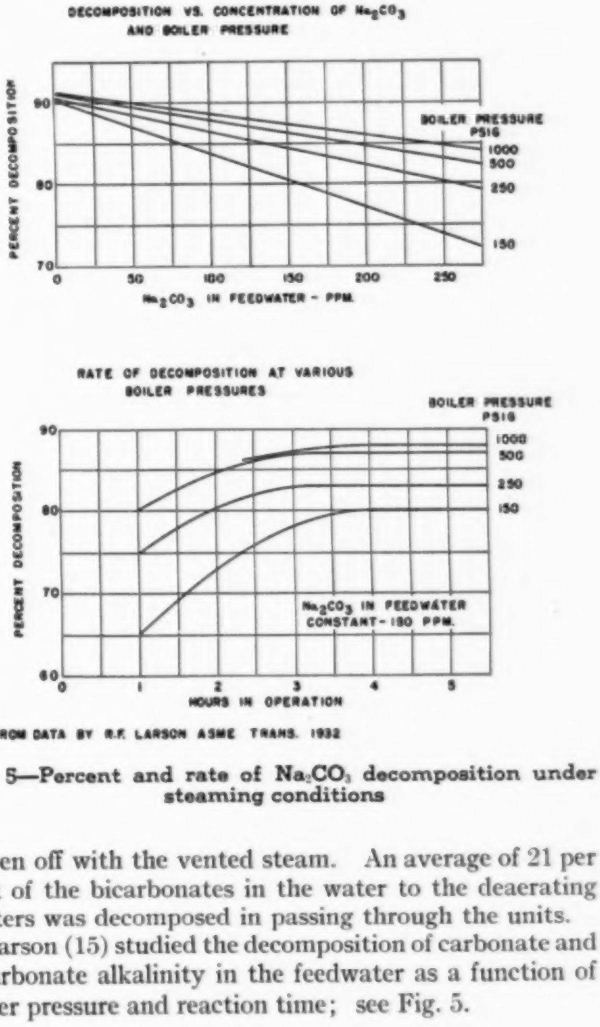

Fig. 5—Percent and rate of Na_2CO_3 decomposition under steaming conditions

Larson (15) studied the decomposition of carbonate and bicarbonate alkalinity in the feedwater as a function of boiler pressure and reaction time; see Fig. 5.

Decomposition of Sodium Sulfite

Alexander and Rummel (16) demonstrated that, under certain conditions, sodium sulfite in the boiler water will decompose; the gaseous phase of the decomposition products had all of the characteristics of the acid anhydride, sulfur dioxide. The aqueous solution of the gaseous phase was corrosive, had the effect of lowering the pH value and provided a reducing medium as would sulfurous acid. These tests were made on boilers operating at 900 psig to 1050 psig and with various pH values in the concentrated boiler water.

Under some conditions, which have not been reported in detail, hydrogen sulfide has been a significant by-

product of the sodium sulfite decomposition. However, based on data now available it appears that sulfur dioxide is of greater importance. In any case, Rummel and Alexander showed that the amount of reducing material found in the condensed steam and the accompanying changes in condensate quality, such as conductivity and pH value, varied proportionally with the concentration of sodium sulfite in the boiler water, the generating pressure and the pH value of the boiler water. The boiler design and other features may influence the result also, and it is desirable to make actual tests on the

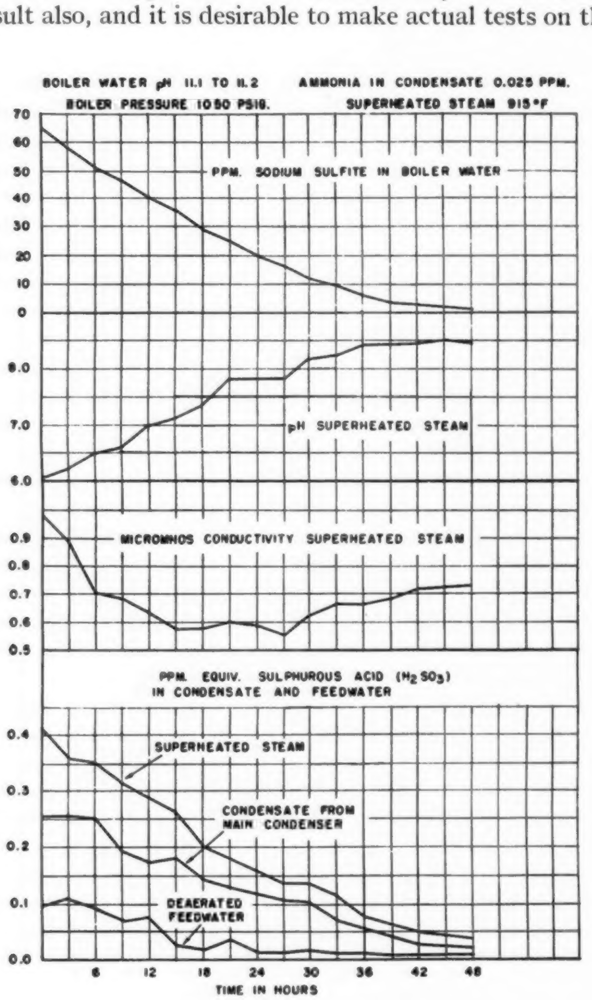

Fig. 6—Effect of sodium sulfite in boiler water on quality of steam condensate and feedwater

boilers in question in order to establish the concentration limits for sodium sulfite at a given pH value in the boiler water to counteract any ill effects of this salt. An example of the decomposition of sodium sulphite at different concentrations in boiler water with a pH of 11.1 at 1050 psig is shown in Fig. 6.

Ammonia and Related Compounds

Many raw or treated water supplies contain ammonia or nitrogen compounds which produce ammonia when heated in the alkaline medium of the concentrated water of boilers and evaporators. This volatile alkaline material is often present in sufficient concentration to neutralize small amounts of carbonic or sulfurous acids formed in the condensate and to provide a more favorable pH value for protection of ferrous metals.

In high concentrations ammonia is aggressive to copper alloys and is, therefore, often responsible for the pickup of copper found in the feedwater. The desirable or objectionable concentrations of ammonia in feedwater composed largely of condensate, as well as in the condensed steam, depends mostly on the amount of acid gases present. If neutralization is effected by the acid and alkaline gases, the results are favorable. The safe limits of permissible concentrations of ammonia to avoid trouble must be determined for each case. At one central steam generating plant, ammonia up to 0.05 ppm in the feedwater has given protection to the ferrous metal in the condensate collecting and feedwater systems without causing excessive pickup of copper from the heat exchange equipment.

Electrolysis Due to Stray Current

In some cases electrolysis resulting from stray currents due to the grounding of electrical apparatus to boilers and related equipment has caused active corrosion. This type of attack is rare in boiler plants but where unexplained corrosive attack is experienced a survey to investigate the possibility of electrolysis is warranted.

Internal Corrosion of Boilers

The corrosion of internal surfaces of boilers, economizers and superheaters is a common occurrence and may be caused by many contributing factors. However, the most usual cause of pitting is the presence of dissolved oxygen in the feedwater; freedom from corrosion cannot be assured when measurable amounts of dissolved oxygen are present in the feedwater supply. This condition is recognized by all power plant operations, but frequently the presence of small amounts (about 0.005 ml. per liter) or the intermittent occurrence of oxygen are overlooked as a cause of active corrosion.

In general, any condition, whether chemical or physical, which results in damage to protective films of iron oxide bonded tightly to the surface of the metal is a primary cause of corrosion and a source of iron oxide deposits. The protective film may be broken by expansion and contraction of the metal due to rapid temperature changes, high pH values maintained in the concentrated water of certain boilers, overheating, steam blanketing, etc. It is frequently difficult to definitely establish the cause, or causes, contributing to such corrosive attacks.

The corrosive effect of water of low and high pH has been observed by numerous investigators. Partridge and Hall (6) have summarized the work of Berland and Van Taack (17) who reported on a series of experiments made at a water temperature of 590 F, and at various pH values. Low pH values in the boiler water may be brought about by contamination of the feedwater with acids, or organic matter which can decompose to give an acid reaction; this can produce local attack. Where there is opportunity for caustic to concentrate, the protective iron oxide film is penetrated and rapid localized attack upon the metal occurs. This type of attack is associated, at times, with embrittlement of the metal.

The authors have investigated several failures due to corrosion resulting from high concentration of caustic in contact with metal surfaces. These failures have been associated with the formation of black iron oxide, either loosely or tenaciously bonded to the metal. This form

of corrosion has been accompanied by the rapid generation of hydrogen. Data obtained from one study where the caustic attack on the boiler metal occurred have been plotted. The hydrogen in the steam was measured in parts per billion (ppb) by a Cambridge Recorder and the boiler water pH value tested hourly. It will be noted that as the pH increases the rate of hydrogen release increases proportionally. Therefore, in cases where there is a tendency for caustic to concentrate within the boiler, it is highly desirable to maintain the pH value of the concentrated water at a point sufficiently low to protect the metal.

In a recent study the authors demonstrated the beneficial effect of limiting the upper pH ranges of the concentrated boiler water in order to control the rate of formation of black iron oxide. In the case in question, boilers operating at about 1200 psig showed no corrosion and a minimum of black iron oxide when maintaining the pH values between 10.2 to 10.5; however, high corrosion rates and rapid production of black iron oxide were experienced at pH values between 10.5 and 11.0. By reducing the pH value in the latter boilers to about 10.5, or slightly lower, the operation was materially improved.

It is not possible to draw any broad conclusions, applicable to all stations, as to the pH levels required to avoid the rapid formation of black iron oxide. However, wherever operating conditions of the individual units are critical, especially with a tendency for the concentrations of caustic, then a reduction of pH values tends to minimize the formation of hydrogen in the steam which is an indication of corrosion rates within the boilers.

Copper in Boiler Water and Black Oxide Production

There has been much controversy as to the influence of copper salts in boiler water on corrosion rates and the formation of black iron oxides. Corey (18) summarized the probable effects of copper as an accelerating factor in the corrosion phenomenon. Copper is present in most boilers and occurs either as small metallic particles or plated out on the boiler surfaces in sheets or in threads. During normal operation the copper is present on the surface of deposited iron or occluded with iron oxides or other deposits. However, after boilers are acid-cleaned, some of the copper deposits are often plated out as a metallic coating.

Some investigators claim that copper in the deposits on tubes has no appreciable accelerating action on the rate of corrosion of steel. Others, including the authors, believe that when copper is in the metallic state and bonded to the boiler metal it can, under certain conditions, appreciably accelerate corrosion. In some cases investigated by the authors, boiler tubes have suffered deep intergranular attack by the hydrogen which was evolved under the deposits. It is believed that the metallic copper may have contributed to the type of corrosion noted in these failures. However, it has been shown that copper is not a constituent essential for this kind of attack.

Although the iron oxide formed in superheaters may not be a main source of iron deposits in boilers, it is an item of significant importance. The rate at which iron-steam reactions may take place in superheater tubes was surveyed by Rummel (19) who showed the amounts of hydrogen produced in operating boilers and superheaters of various types and pressures. This reaction is as follows:

$$3Fe + 4H_2O \rightleftarrows Fe_3O_4 + 4H_2$$

Fellows (20) reported on the rate of hydrogen production during a series of tests made with plain steel and chrome steel tubes and at maximum steam temperatures of 865 F to 1143 F. It was concluded from this work that pressure alone was not significant, but that the rate of hydrogen evolution would be increased as the metal temperature over which the water or steam is passed is increased. However, it was shown that the iron oxide coating which was produced on the superheater tube surfaces retarded the reaction rate appreciably. Chrome alloy steel tubes were found to be much more resistant to this form of attack than mild steel for which the upper metal temperature was limited by the boiler manufacturer to approximately 900 F.

Later Solberg, Potter and Hawkins, (21), (22) and Rohrig, Van Duzer and Fellows (23) showed by a series of experiments the actual loss of metal from the surface of the steel and chromium steel alloys in contact with steam at temperatures ranging from 1000 F to 1400 F. It was found that the curves for inches of penetration versus temperature were similar in shape to the curves for hydrogen evolution versus temperature. It was concluded that chromium in steel in amounts as small as 1.25 per cent had a definite effect in reducing the rate of the iron-steam reaction. Increasing the chromium to 7 per cent had a much more decided inhibiting effect. Alloys containing 12 to 18 per cent of chromium were found to suffer a negligible rate of attack at 1100 F. or somewhat higher.

The need for chrome and chrome-molybdenum alloys for high-duty superheater service is now well known and selection of such material is standard practice.

Recent tests for hydrogen evolution made at a central power station, where the superheated steam temperature was 915 F and during the time that traces of boiler water leaked into the steam, showed that when the alkaline boiler water, containing other solids, was added to the steam the iron-steam reaction was accelerated to a marked degree. Therefore, the test results with pure steam may not hold if alkali and other boiler water salts are added to the steam.

Corrective Measures

The presence of iron oxide in the steam-water cycle can be greatly minimized in new installations by meticulous cleaning of the equipment and miscellaneous piping before starting up the station. In all new stations there is considerable mill scale and iron rust on the surfaces of the equipment. Ordinary flushing out with water is only mildly effective. Boiling out of the steam generators with alkaline solutions is required to remove the oil and other adherent materials and does much to get rid of mill scale and similar deposits. The cleaning operation should include removal of any loose materials not carried out by the blow-down and drain water. In some cases this operation is followed by acid cleaning. In like manner, the piping, feedwater heaters, turbine condenser and storage tanks should be thoroughly cleaned.

After a short period of initial operation, boilers and other equipment should be taken out of service and again

cleaned to insure complete removal of the various loose materials. The initial operating period of the new equipment often includes frequent starting and stopping, which is accompanied by the entrance of air into the system. This causes rusting of the metal surfaces and the carrying of rust and loosened mill scale into the boilers. Such intermittent service, if not carefully controlled, can do much damage.

During periods of maintenance or overhaul of boilers and auxiliaries it is desirable to make a thorough inspection of the boilers and other equipment. Too frequently these inspections are inadequate because of the desire to limit the outage periods.

Correction of pH by Volatile Alkaline Materials

At many central steam generating stations there is sufficient ammonia present in the makeup water to neutralize the carbonic acid in the condensate. Many European stations have added ammonia to the feedwater or steam to affect this neutralization. In a well designed and well operated central station in this country, as little as 0.02 ppm of ammonia applied to the steam has been sufficient to maintain the pH of 8 in the condensate.

During recent years volatile amines have been applied to the steam-water cycle in medium- and low-pressure plants, where the steam temperatures did not exceed 700 F, to raise the pH value of the condensate returns. The amines act in much the same way as ammonia; it has been indicated that ammonia may be one of the decomposition products.

At temperatures above 700 F., the amines decompose; studies have shown that at 915 F the rate of amine decomposition is rapid.

Frequently it is impractical to employ volatile alkaline materials toneutralize the condensate returns in industrial plants since contamination of process steam cannot be tolerated. Careless use of alkaline products can cause rapid deterioration of copper alloys. Therefore, the use of volatile products such as ammonia and amines should be given careful consideration prior to employing such treatment for the protection of condensate return lines. The control of such alkaline treatment to protect the return lines should be meticulous and delegated to trained, responsible personnel.

Recirculation of Boiler Water

Re-circulation of a small portion of concentrated boiler water from the continuous blow-down line to the feedwater for the purpose of raising the pH value in the feedwater supply has been employed successfully at a number of plants. In most cases with which the authors are associated, the plants were central stations utilizing evaporated makeup. Local conditions should be carefully investigated prior to re-circulating boiler water for, if there is appreciable hardness in the feedwater, adherent deposits can form in stage heaters and economizers.

The corrective measures incorporated in the foregoing discussion of various corrossive conditions can be summarized as follows:

(*a*) The CO_2 content of the steam and condensate should be maintained at as low a value as may be possible. The permissible upper limit will vary with the operating conditions and observations.

(*b*) The velocity flow of the condensate returns should be held to a maximum figure commensurate with the concentration of CO_2 in the condensate.

(*c*) The sulfite concentration in the boiler water should be limited to prevent decomposition which results in entrainment of corrosive acid materials in the steam.

(*d*) Feedwater of low pH value should be treated to raise this value above 8.2. The most desirable pH level may be determined by observations at the power station being studied.

(*e*) In some boilers the pH value of the concentrated boiler water must be held below a pre-determined upper limit to minimize the internal corrosion due to caustic attack. The hydrogen evolution, used as an index of the corrosion rate, plotted against the pH of the boiler water can be used to determine the upper permissible pH value.

(*f*) Grounding electrical equipment to the boiler or related structures should be avoided in order to guard against creating electrolytic action.

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Unsolved Problems in Air Pollution Control*

By H. B. Lammers†

Among the factors mentioned as often interfering with effective control are political mediocrity of appointees, unwillingness of the public to pay for the desired results and lack of proper standards of measurement. Constructive suggestions are offered for administrative procedure, educational programs and technical problems to be solved by research.

THERE are a variety of unsolved problems still requiring solution in air pollution control. These touch many fields of activity and embrace a multitude of subjects. Some of the major ones will be discussed here although the order given does not necessarily indicate their relative importance; they are: (1) municipal; (2) economic; (3) administrative; (4) standards of measurement; (5) health relationships; (6) educational; (7) technical; and (8) research.

Municipal Problem

One of the greatest drawbacks to effective air pollution control is its present dependence on the political organizations of our cities. In only a very few cities has the office of air pollution control been reasonably divorced from politics. The salaries paid municipal department heads in most cases determine the salary to be paid the administrator of air pollution control. An inspector in the Health or Building Department or some other city employee may be appointed to such a position even though most ordinances specifically require a higher standard of qualification.

One solution to this political subjugation and political mediocrity is the establishment of a commission or board with the authority to determine matters of policy and the selection of a suitable candidate. Selection must be based on proper qualifications, because a qualified administrator is more important to the success of the control program than the ordinance he is charged with enforcing. A capable administrator must have the necessary background of experience to prepare, interpret and enforce the rules and regulations. This work is not something to be entrusted to an amateur, and since time is of the essence, years of experimentation at the taxpayers' expense cannot be permitted.

There are numerous instances where an air purification program has been launched with a great deal of fervor and fanfare but failed to continue. The fanfare dies, the fervor rapidly subsides, and the program becomes a short-lived campaign. The reasons for these failures are many, but the most important are the lack of a proper appreciation of problems involved, administrative incompetence, and inadequate financial support. Even though cities want air pollution control, few are willing to pay for it. Only a very few cities have provided adequate funds to assure a successful long-range program. Most cities are still thinking in terms of too little money. They hope for a miraculous method of improvement accomplished at little expense and in a relatively short time, as proclaimed by some other cities.

Air pollution control programs cannot and will not endure without sustained, active and forceful public support. The air pollution control administrator without such support is doomed to defeat.

Economic Considerations

The Foreword to the example sections for a Smoke Regulation Ordinance prepared by the Model Smoke Law Committee of the ASME says, "At the outset it is well to recognize that all differences of opinion and all controversy relative to a smoke ordinance are basically economic. The necessary compromises and agreements could be more readily reached if this were constantly kept in mind.... What is considered is some economic compromise. The success and life of the ordinance depends upon the sagacity of this compromise."

To this we can add Amen; certainly this statement makes sense. How much will the people individually or collectively pay for air purification? How much can they afford to pay? What can industry afford? More specifically, what can the marginal industries afford? Contrary to common belief, one never gets anything—even clean air—for nothing. Despite stories to the contrary, it is only rarely that the cost of removal and disposal of air pollutants can be recovered. Except in these rare cases, any change in equipment or processes must be eventually reflected in increased cost to someone.

The industrial air pollution problem could be alleviated somewhat by proper zoning, particularly as it applies to new industries. Zoning should not only be considered from the viewpoint of protecting residential areas from encroachment by industrial installations, but also from the viewpoint of protecting the latter from the encroachment of residential developments.

Then there is the question of fuel restrictions. While supply and demand and the law of averages will eventually catch up with us, any improvement from this approach to the control problem is reflected in higher prices, sometimes for a product of reduced utility value. People who can least afford this kind of overemphasized im-

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provement are hit the hardest. They are the ones who foot the bills out of all proportion to the benefits that may accrue to them. The solution to the economic problem is to be found in a sane policy with respect to fuel and equipment. It is to the credit of many present administrators that such a policy has been adopted.

Administrative Procedures

The engineer who administers an air pollution control ordinance efficiently is the mainspring of its successful application. He can insure the success of a program even when he has to work with a weak ordinance. The opposite of this case does not follow however. The best legal control instrument that can be written will fail if its administrator is incapable of carrying out its provisions, wisely.

There is a great deal of record and paper work necessary in the efficient handling of a control engineer's responsibilities. Properly done and properly maintained, this part of the organization of a control department becomes the foundation upon which success and accomplishment can be built. Altogether too many existing "smoke" departments are ineffective because these primary requirements are lacking or considered to be unnecessary.

Another problem of moment which has received too little consideration from the average air control engineer is the paramount necessity of selling the importance of the program back to his supporters in the municipal family, to committees and to the general public. There are so many subjects which engage the momentary interest of the public that air pollution control has to compete for the public favor with all of these interests. If this selling job is not handled on a continuing basis, the program may soon be on the defensive.

A qualified administrator must be technically proficient in the field of combustion. He must be a good organizer; adept at meeting the public; be capable of establishing a good system of office procedures and accurate records; and able to prepare and interpret a set of rules and regulations that are practical and equitable.

The answer to the administrative problem is the proper training of personnel who could command remuneration levels above those now paid. Administration handicaps are overcome by employment of engineers with adequate experience and with adequate qualifications.

Standards of Measurement

The Ringelmann Chart is outmoded. A new method or instrument for measuring smoke density is sorely needed. It must be practical and easily understood. Likewise, we need a more practical and simple method of testing or measuring fly ash emission. Conservative estimates place the cost of employing the often quoted ASME Standard Procedures as $500 for the occasional spot check. All ordinances are meaningless without such a method. The same holds true for other pollutants. We must make sure the standards set are sensible and conservative.

Methods of making observations are likewise subject to criticism. By definition, an observation should mean the same thing in New York City as it does in St. Paul. Is observation to be made of chimneys in a given area and estimated; or are the individual stacks to be examined and recorded, each an observation? The same criticism of method applies to making observations of locomotives. How can observations be made at a distance if the Ringelmann Chart is to be used as the standard? How, for example, could the Ringelmann Chart be used effectively in the city of New York? If the Ringelmann Chart is not used in the previous determination, do we then have a legal violation? An observation should be made in a specific manner, for a specific time and at a specific distance from the smoke source.

Most programs fail after a time for want of a standard of measuring the improvement or evaluating results, and hence these cannot be interpreted to the public. After 40 years of smoke prevention work, we have not standardized on a single method of procedure. Let's take one example, dustfall sampling. The limitations of analyzing dustfall are recognized but for comparative purposes the procedures must be identical or they will be of little practical value. When a city wishes to advertise its improvement, and reduction in dust fall (for years it was called sootfall—a term now abandoned for obvious reasons) suits its purpose, it uses such values. If values are too high, sometimes sample cans are moved to different locations. If still too high, any practical advantage in this method of determination is usually disclaimed. If the figures are low, everybody gets a copy of the report.

Some cities use visibility as a gage for measuring improvement when it suits their purpose. What matters if the airport is 30 miles outside the city; naturally this is a better location for taking such readings than perhaps some downtown spot! Visibility readings, properly taken and recorded, and properly interpreted are satisfactory for the purpose. But they must be taken for a long period of time using the same standards to be of any permanent value.

Some cities use sunshine hours for measuring results, although the Weather Bureau places absolutely no reliance on such data to determine air pollution. One can place no credence consequently in any system of using sunshine hours for recording improvement.

The day is not too far distant when the public will demand that results be attained and facts presented. No longer will we be able to confuse the public; that day is about over. The use of improper standards or comparisons does much to discredit an administrator who is attempting an honest job. A true standard of measurement is imperative if we are ever to get the problem under control and prove that improvement has been accomplished. Progress is being made in cities such as Cleveland, Columbus and Los Angeles in determining suitable standards which can be used for this purpose. We can solve the standards of measurement problem by adopting such standards immediately regardless of whether they are totally foolproof at the moment.

Air Pollution and Health

This is another unsolved problem. What ingredients in the air of cities are harmful to health? In what proportion do they exist? Many false claims have been made in the past and still persist as to losses encountered due to lack of sunshine, deaths due to cancer or other ailments attributed to murky skies. What are the truths behind these statements? Should these claims be accepted without challenge?

Educational Programs

Success of air pollution control programs depends in a large measure on continued programs of education. This includes education of the designing and consulting engineer; education of the plant operator; of the general public; and even of the smoke inspector. To whom, for example, does the young smoke engineer go for advice? Where is he to get his information? To whom do the people or the public go with their problems? Do they get facts or fiction? Unless we supply the facts to all those seeking this information, they will turn to volunteer's with an axe to grind or to theorists of which there are already too many.

There is today entirely too much energy given to repetition and discussion of the same subjects and problems. For the uninformed, why not make an index of all available material for immediate reference; and prepare a handbook of general information? We need, too, a clearing house for all information, a library in which could be found all the latest information, such as standard methods of procedure on firing; design and application of boilers and heating equipment, collector data, bibliography of smoke abatement, etc. Information that is now available deals for the most part with the abatement of smoke only.

Technical Problems

Many technical problems pertaining to air pollution and its control still remain to be answered. Some of these problems will never be solved by the smoke abatement engineer or the air pollution control engineer working alone. Answers will be found by combining the knowledge and professional skills of all who work with this subject including the engineer, chemist, manufacturer, medical authority, health authority, or meteorologist. Even with all this assistance the solution to some of the problems will be difficult to attain in the immediate future.

Standards of emission are established for various types of equipment without any idea as to whether they are practical in application. Examples are to be found in standards that are applied to brick kilns, fumes from electrical furnaces, from chemical and metallurgical plants, coke ovens, bessemers, open hearths, oil refineries, cupolas, incinerators, as well as process exhaust of all description. Credit must be given Los Angeles control authorities for their practical approach in arriving at standards for various operations. Provisions in most city ordinances have been selected at random and the reasons why they have not been enforced is very evident. Allegheny County, Pennsylvania, also realized that it could not apply overall emission limits without due consideration for the problems involved. Hence, the many exceptions that were made for industry, which also poses the question—if some industries are exempted, why not the users of domestic furnaces?

And what about standards for fuel-burning equipment? Such standards vary all over the map as indicated by the recent Bureau of Mines Circular No. 7557. Would it not be better to have a minimum set of rules and regulations which could be applied in a general manner than to modify standards day by day for installers by individual decisions which depend upon the exigencies of the moment? Circular No. 7557 is an excellent summary of existing regulations which speaks for itself.

Rules and regulations should be prepared and made available to all installations; but naturally judgment will have to be exercised with those pertaining to the large power and process installations. Such rules and regulations should be based on what can be effectively accomplished with them rather than on wishful future expectations. For example, some standards applicable in Los Angeles may be neither necessary nor desirable in a midwestern city considering an air purification program for the first time, but too often such rules and regulations are adopted *in toto* as the easy way to get started.

Research

The necessity for research and further study of the air pollution problem was recognized by an authority[1] several years ago and perhaps it is still not too late to review this excellent paper. The questions asked still remain unanswered for the most part.

1. What should atmospheric pollution be considered to be?
2. What percentage of this pollution came from industry, commerce or domestic furnaces; how is it measured?
3. What is the variation of pollution with time, i.e., by years, seasons, days, hours?
4. What quantity of pollution is present in a city's atmosphere?
5. What practical means can be adopted to reduce air pollution both by prevention and removal?
6. What quantitative measures can be adopted; what qualitative measures?

To this list could be added many more questions. Isn't it about time an attempt is made to answer these questions one by one? If research is required, why not start now. The longer we wait, the longer we operate in the dark, the longer it will take to solve these problems if we are ever to solve them. Again we must recognize the soundness of approach employed in the attack on the smog problem on the West Coast, regardless of the apparently insurmountable obstacles they have to overcome. Why not have specific research assignments undertaken by the various smoke abatement engineers? These could be planned by a technical committee of smoke abatement officials based on the needs to be determined.

[1] "Factors Rarely Considered in Smoke Abatement" by Henry F. Hebley, Research Consultant, Pittsburgh Consolidation Coal Company, Combustion, vol. 18, March 1947, pp. 44-48.

Calcium-Base Sulfite-Liquor Burning Tests

By F. H. Coldwell* and E. H. Kennedy†

The following is based on a report to the American Pulp and Paper Mill Superintendents Association on the results of tests made to obtain certain basic information on the burning of calcium-base sulfite liquor, of approximately 52 per cent solids content, for steam production. Comparative runs were made with mechanical and steam atomization supplemented with pulverized coal.

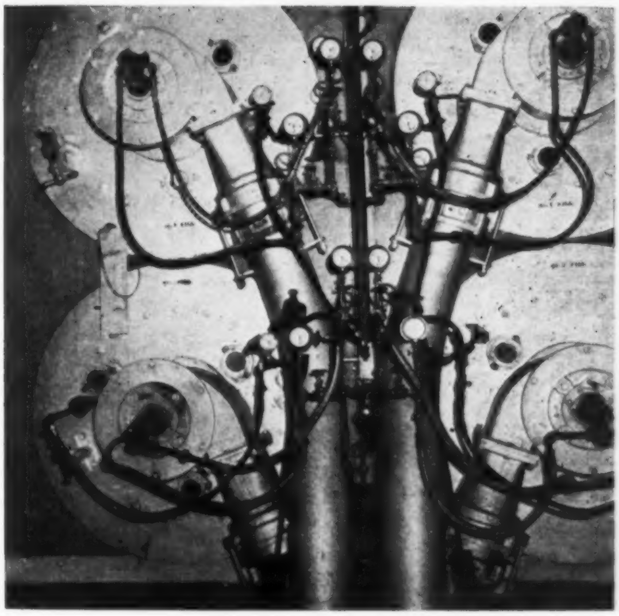

Fig. 1—Burners arranged for burning liquor

THE Sulphite Pulp Manufacturers Research League in 1949 installed a single-effect Rosenblad evaporator at Appleton, Wis., to determine the feasibility of evaporating spent sulfite liquor and the difficulties which would be encountered in this work. This was a part of the League's long-range program of experimentation to utilize this material and thus provide a method of abating the stream pollution which is attributed to the liquor.

Finding that the equipment which was installed would produce sizeable quantities of a liquor of about 52 per cent solids, the League considered it logical to continue the work further and find out what could be done in burning it in commercial boiler units of the type generally in use by the League's members.

The Nekoosa, Wis., plant of Nekoosa-Edwards Paper Company had just installed a Combustion Engineering-Superheater, Inc., steam generating unit with a completely water-walled furnace and this company was approached to see if, as a League member interested in pollution abatement, this unit could be made available for such tests.

Accordingly, a meeting was held in the latter part of January 1950, at which representatives of these three organizations discussed the part each could play in the burning of this material. The League obviously would furnish the liquor, Combustion Engineering was in a position to furnish various sizes and types of burning nozzles and technical personnel to conduct tests and evaluate results, and the Nekoosa-Edwards Paper Company could furnish operating labor, install equipment and supply its technical force to collect data and prepare certain parts of the results.

Tests were begun on March 28, 1950, and continued until May 3. The different types of fuel injection guns were calibrated for capacity at different pressures and at the end, two 4-hr tests were run, using four mechanical atomizing burner nozzles and then four steam atomizing burner nozzles.

Object of Test

It is well known that burning of calcium-base sulfite liquor is an accomplished fact in Sweden and some work has been done in this country on liquor from this base. The idea back of these tests was not to duplicate these experiences, but rather to supplement them. It was for this reason that the completely water-cooled furnace was chosen as the type on which the burning experiments were to be conducted.

Some of the points to be cleared up included the efficiency at which the liquor could be burned in such a unit, the amount of liquor which could be consumed in relation to the total fuel used, the completeness of combustion, and the possibility of controlling the possible fly ash nuisance with a commercial fly ash collector which was operating successfully on pulverized coal.

The Fuel

Calcium sulfite liquor as it comes from the digesters may contain from 10 to 14 per cent solids, depending upon digester operation and methods of cooking the pulp. An early sample of concentrated liquor from Appleton showed the analysis given in Table 1.

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† Test Engineer, Combustion Engineering-Superheater, Inc.

TABLE 1

Analysis of the Liquor

Total solids, per cent	51.7
pH value at 70 F	4.0
Viscosity at 70 F	
Centipoises	750
Saybolt seconds, Furol	310
Seconds, Engler	90
Viscosity at 200 F	
Centipoises	25
Saybolt seconds, Furol	17
Saybolt seconds, Universal	120
Seconds, Engler	3.5
Specific gravity at 70 F	1.27
Specific gravity at 200 F	1.23
Density at 70 F, lb per gal	10.60
Density at 100 F, lb per gal	10.26

Analysis of Dry Solids

Carbon, per cent	41.50
Hydrogen, per cent	4.75
Oxygen, per cent	38.72
Nitrogen, per cent	0.13
Total sulfur, per cent	6.00
Combustible sulfur, per cent	4.46
Ash after burning, per cent	10.44
Btu per lb of dry solids	7990
Btu per lb of combustible	8930

Analysis of Ash from Laboratory Burned Sample

Total calcium as CaO, per cent	58.02
Total sulfate as SO_3, per cent	32.93
Carbon dioxide, as CO_2, per cent	7.37

Probable Combination

Calcium sulfate—$CaSO_4$, per cent	56.48
Calcium carbonate—$CaCO_3$, per cent	16.78
Calcium oxide CaO, per cent	25.37
Calcium sulfide, per cent (by diff.)	1.37

	Reducing Atmos.	Oxidizing Atmos.
Initial deformation temperature	2660 F	2380 F
Ash softening temperature	2670	2390
Fluid temperature	2680	2400

The Boiler and Furnace

The spent sulfite liquor was burned in a standard VU two-drum steam generator rated at 125,000 lb of steam per hour at 400 psi, and 700 F temperature at the superheater outlet. This boiler is normally fired by four turbulent burners in the front wall with pulverized coal furnished by two C-E Raymond bowl mill pulverizers. Drum center distance is 22 ft. The furnace is completely water cooled, is 17 ft 10 in. wide and 16 ft $7^7/_8$ in. deep. Following the boiler is a tubular air heater and a Western Precipitation mechanical ash collector ahead of the induced-draft fan.

Sulfite Liquor Equipment

Fifty-two percent (approximately) sulfite liquor was stored in a 10,000-gal tank car just outside the boiler house. It was pumped, by means of a gear pump driven by a 10-hp motor, to either of two wooden tanks inside the boiler house. These tanks were used for measuring the volume of liquor burned during the tests. One tank held about 350 gal and the other about 600 gal, and each was supplied with a steam heating coil in the bottom. From the wooden tanks, the liquor flowed by gravity through either side of a twin strainer to the suction side of a DeLaval IMO pump of 1800 to 2000 gal per hr capacity driven by a $7^1/_2$-hp motor. This pump discharged to two indirect steam heaters connected in series and filled with tube bundles. From the heaters the liquor was led to the burners by suitable piping and valves.

The "guns" or atomizers used for burning the liquor were of both the mechanical-atomizing and steam-atomizing types. They were similar to the standard types of oil gun or atomizers found on the market. The mechanical guns used were equipped with tips of 250 gal and 350 gal per hr capacity. Three kinds of steam-atomizing guns were used and equipped with tips to burn from 200 to 400 gal per hr. It was originally anticipated that it would be necessary to burn 400 gal per hr per gun to handle the liquor from a 100-ton sulfite mill, assuming a solids recovery of 90 per cent of 2200 lb per ton of pulp. Actually, however, a little more liquor may have to be burned as one plant in the Wisconsin area reports 2400 lb of solids per ton of pulp.

Results of Tests

Most of the earlier tests were of short duration and run mainly for the purpose of calibrating the various burner tips for capacity. The last two tests were of longer duration and the results are more reliable. Test No. 14 was run on April 21 for a period of four hours, using four mechanical guns. The coal-burning rate was adjusted as low as possible on the four burners and out of a total load of 98,000 lb of steam per hour, 40 per cent of the steam was generated by the sulfite liquor. Liquor was burned at the rate of 1385 gal per hr. The rate of liquor burning was limited by the size of the liquor burner tips and the available liquor pump pressure.

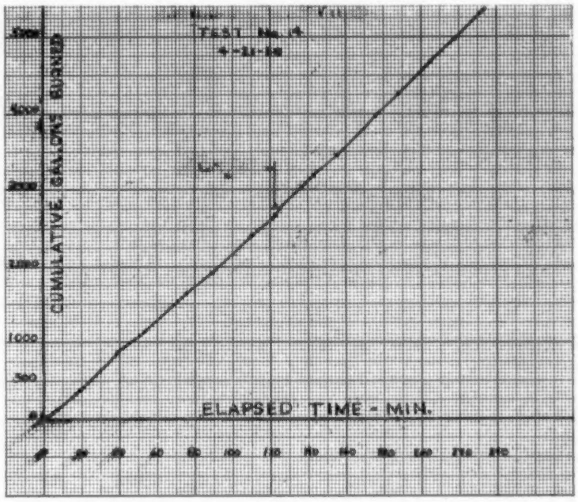


Fig. 2—Rate at which liquor was burned with mechanical guns

Fig. 2 shows the constant rate at which the liquor was burned with mechanical guns. Here elapsed time is plotted against cumulative gallons burned. This plot indicates that, under the conditions of this test, the sulfite liquor was handled with ease and continuity. Table 2 lists pertinent data obtained from four-hour Test No. 14 using four mechanical burners:

TABLE 2—RESULTS OF FOUR-HOUR TEST WITH MECHANICAL BURNERS

Total liquor burned, gal	5541
Liquor burned per gun, gal per hr	346
Total coal burned, lb	27,000
Lb of steam per lb of coal, from previous period	8.75
Total steam from coal during test, lb	236,000
Total steam made during test, lb	392,000
Total steam made from sulfite liquor, lb	156,000
Total liquor solids burned during test, lb	30,800
Actual lb of steam per lb of dry liquor solids, lb per lb	5.0
Equivalent lb of steam per lb of dry liquor solids, lb per lb (test results)	6.0
Equivalent lb of steam per lb of dry liquor solids, lb per lb (theoretical)	8.225
Indicated efficiency, per cent	73.0
Average CO_2 leaving I.D. fan, per cent	15.4

In the foregoing calculations, the assumption was made that coal was burned with the same efficiency during the liquor-burning test as it was when burning coal alone. During the test, samples of liquor, coal and ash refuse

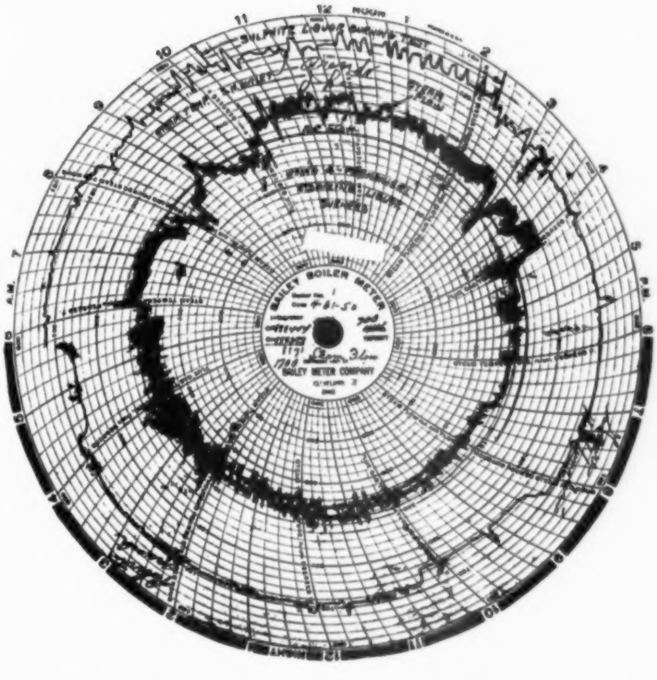


Fig. 3—Steam flow-air flow chart for Test No. 14

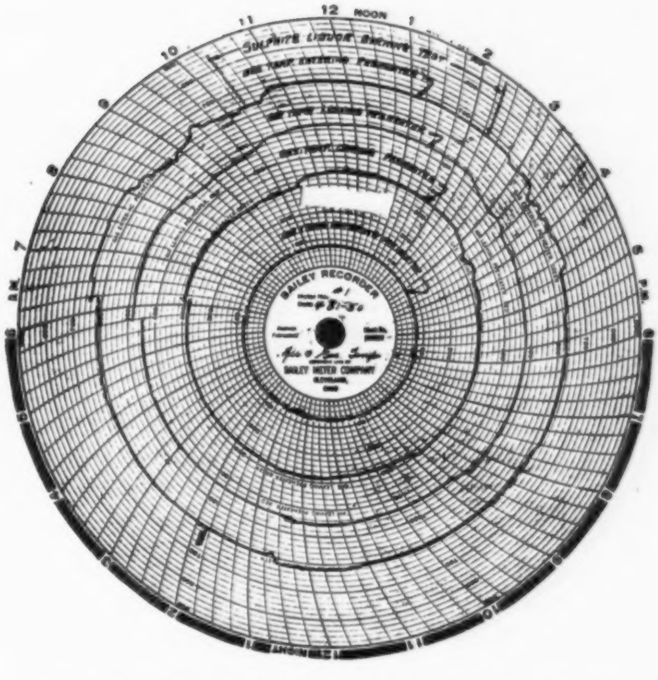


Fig. 4—Air and gas temperatures during Test No. 14

were taken so that heat-balance calculations could be made when the results of the analysis were available in order to determine more accurately how much steam was made from sulfite liquor. Figs. 3 and 4 show the steam flow-air flow, and steam temperature and air and gas temperature charts, respectively, for Test No. 14. During the test the unit was put on hand control. Soot blowers were not used during the test period.

Test No. 15 was run on April 26 for a period of $2^3/_4$ hr using four steam-atomizing guns. The coal was cut as low as possible on the two upper burners and completely cut off of the two lower burners. Two small oil burners using about 25 gal of oil per hour each were used in the two lower burners to maintain close ignition on the lower liquor guns. Out of a total steam output of 77,000 lb per hr, 48 per cent was made by the sulfite liquor which was burned at a rate of 1370 gal per hr. This rate could have been increased but was limited to this figure because of the small quantity of sulfite liquor on hand and the desire to run as long a test as possible.

Fig. 5 shows the rate and continuity of burning the sulfite liquor during Test No. 15, using steam-atomizing liquor guns, and Table 2 contains a summary of the test data.

TABLE 3—TEST DATA WITH STEAM ATOMIZING

Total liquor burned during test, gal	3768
Liquor burned per gun, gal per hr	344
Total coal burned during test, lb	11,200
Total oil burned during test, lb	1100
Lb of steam per lb of coal from previous period, lb per lb	8.61
Total steam from coal during test, lb	96,432
Total steam from oil during test, lb	13,930
Total steam made during test, lb	211,345
Total steam made from coal and oil, lb	110,362
Total steam made from sulfite liquor, lb	100,983
Total liquor solids burned, lb	20,592
Actual lb of steam per lb of dry liquor solids, lb per lb	4.9
Equivalent lb of steam per lb of dry liquor solids, lb per lb (test results)	6.1
Equivalent lb of steam per lb of dry liquor solids, lb per lb (theoretical)	8.225
Indicated efficiency, per cent	74.0
Average CO_2 leaving I.D. fan, per cent	15.3

Figs. 6 and 7 show the steam flow-air flow, and steam temperature and gas and air temperature charts, respectively, for Test No. 15.

An attempt was made during this test to measure the quantity of steam used for atomizing the liquor. These figures may be approximate and will be checked again. They indicate that about 0.08 lb of steam per pound of liquor was used for atomization.

Heat Balance

It has previously been stated that the pounds of equivalent steam from and at 212 F realized per pound of dry solids from the sulfite liquor was 6.0 or a little better. This value was based on the assumption that the pounds

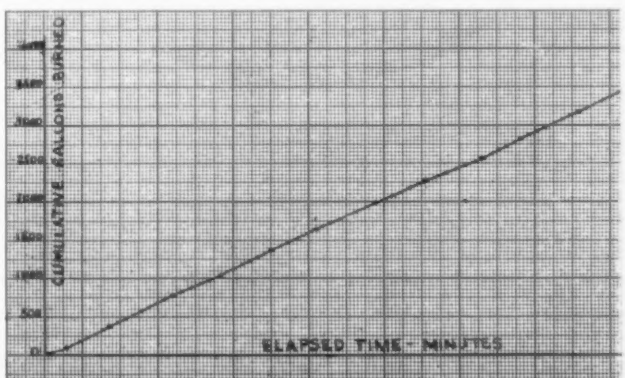


Fig. 5—Rate of burning liquor with steam-atomizing guns

of steam from one pound of coal was the same during the test with sulfite liquor as before the test with coal alone. After having the coal and liquor analyzed for heat values and the refuse samples analyzed for percent combustible, heat balances were made for Test No. 14 with mechanical atomizers and Test No. 15 with steam atomizers. Heat balance calculations showed the following results:

Test No. 14	
Mechanical atomizers, in lb of equivalent steam per lb of dry solids...	6.0
Heat to steam in per cent of heat in dry solids..................	75
Test No. 15	
Steam atomizers, lb equivalent steam per lb of dry solids..........	5.82
Heat to steam in per cent of heat in dry solids..................	72.3

This lower steam production and efficiency from steam atomizers is mainly due to the added water vapor loss from the atomizing steam.

Fly Ash Control

Data collected for Test No. 14 have been calculated to show the amount of refuse escaping past the flue dust collecting system. About 20 per cent of the total refuse escaped up the stack to the atmosphere. Some refuse is, of course, deposited in the setting, so this figure of 80 per cent represents the overall unit collection rather than the true multicyclone collector efficiency which would be less, depending on the amounts dropped before reaching the collector.

In making calculations of the amount of refuse which would be collected in different parts of the boiler setting, it was assumed that 12 per cent of the ash would be collected in the ash pit, $6^1/_2$ per cent in the first pass and $6^1/_2$ per cent in the second pass hoppers. This is the experience which obtains with this type of boiler setting on pulverized coal. On this basis, the dust collector received approximately 75 per cent of the total ash. A little more than 26 per cent of the refuse entering the Multiclone flue dust collector escaped to the atmosphere, thereby showing a collection efficiency of about 74 per cent. Swedish technical literature indicates mechanical collector efficiencies of from 60 to 75 per cent when burning sulfite liquor.

Mechanical collectors of this (Multiclone) type base efficiency on varying factors, one of which is the percentage of material to be collected below a 10 micron size. Size determinations have been made on samples of the material passing the dust collector on tests using coal only and the combination of coal and sulfite liquor as fuel. These determinations show remarkable size similarity in the material which escaped to the atmosphere for the two tests. The results indicated that for pulverized coal only, 78 to 84 per cent of the material escaping to the atmosphere was less than 10 microns in size. For the combination fuel of coal and sulfite liquor, 76 to 81 per cent of the material escaping to the atmosphere was less than 10 microns in size.

Effect of Concentrated Liquor on Equipment

The auxiliary equipment of transfer pump, liquor feed pump, indirect liquor heaters, valves and piping previously mentioned were examined after the tests for any evidence of wear, scaling and deterioration. This was all part of the regular paper-mill equipment and no special materials were involved.

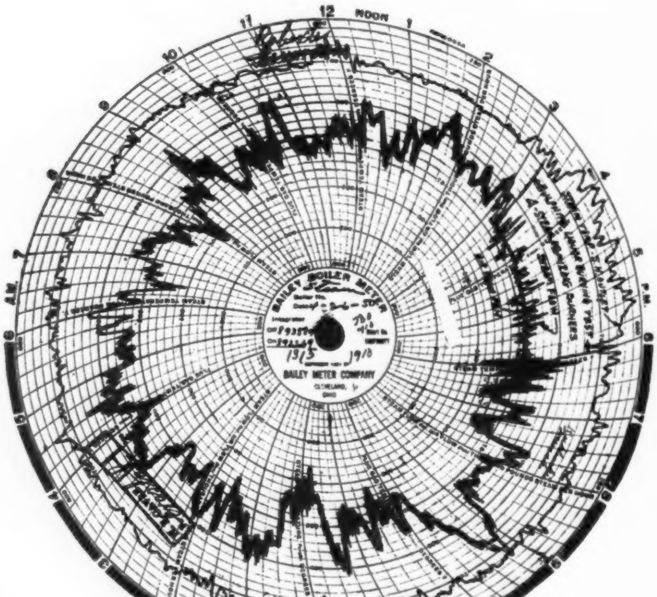


Fig. 6—Steam flow-air flow chart for Test No. 15

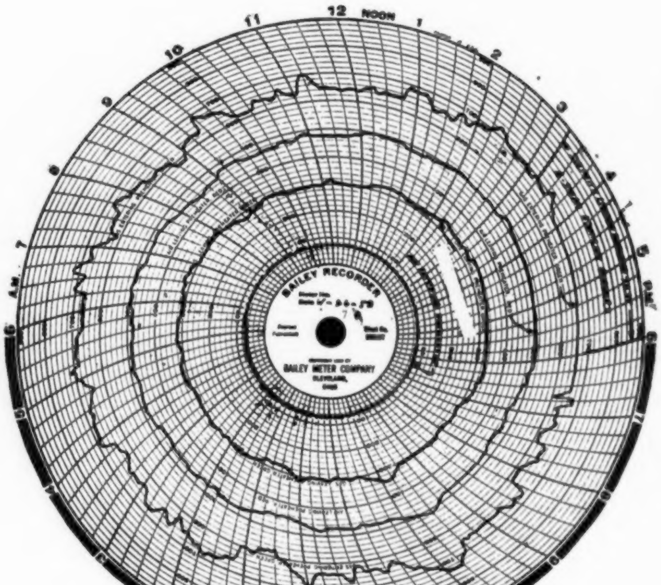


Fig. 7—Air and gas temperatures during Test No. 15

It had been thought that rapid deterioration might take place but no evidence was discovered to indicate any serious immediate attack had occurred on these ordinary cast-iron, steel and bronze parts. This does not in any way indicate that these parts are suitable for continuous use as the exposure was only on the order of 35 hr.

There was rapid erosion of the carbon-steel burner tips through which the liquor was sprayed to the furnace, which experience has been repeated in another plant conducting similar burning trials. A set of steam-atomizing tips were tried which were made of hardened tool steel. Although these were used only a short time, they did not show appreciable wear. Only a longer test will indicate how long they will stand up. Another pair of steam atomizing guns showed no appreciable wear on the internal brass parts for the total time used, about 15 or 16 hr. The outside part of the tips, made of mild steel, did show some deterioration due to abrasion or corrosion in-

dicating that such parts should be made of a different material.

The mechanical-atomizing tips, including the cap and breaker plate, were made of mild steel which had been case-hardened. These tips showed appreciable wear on the inside faces which were subjected to the high velocity and swirl of the liquor. They had been used probably about 15 hr and the indications are that such mechanical tips would have to be made of much harder abrasion- and corrosion-resisting material. General indications are that steam-atomizing tips made of the proper material with their lower liquor velocities will stand up longer under this service than mechanical atomizing tips. This is the experience of companies manufacturing guns burning similar corrosive and abrasive liquid fuels. No particular scaling of the indirect liquor heaters could be determined, but again, the exposure was short, and this may not be indicative of longer commercial service.

General Remarks

It does not appear from the short tests at Nekoosa or from work done in Sweden, that any serious trouble will be encountered from furnace, boiler tube or superheater tube fouling as long as the liquor is atomized finely enough and the furnace is large enough to burn the fuel completely before it leaves the furnace.

The problem of handling the ash is similar to that of pulverized coal ash and can apparently be accomplished in about the same way and by the same means. However, from $1^1/_2$ to 2 times as much ash results from burning sulfite liquor as from coal for the same heat input.

Trouble from corrosion of metal surfaces because of the presence of SO_2 and small quantities of SO_3 should not occur as long as gas-touched surfaces are kept well above the dew point of the gases. It has been stated in the literature from Sweden, that the dew point of flue gases resulting from the burning of sulfite liquor alone is about 215 F. Some thought should also be given to the effect of these gases on stacks if the gas temperature gets down to the dew point before leaving the stack.

The problem of disposal of spent sulfite liquor by burning is one made up of several phases. To satisfy the demands for abatement of pollution, a maximum percentage of the liquor produced in the process must be collected. To satisfy the needs of the power house and keep combustion losses at a minimum, it must be concentrated by evaporation to as great a degree as can be done practically. To permit economical evaporation, the liquor must be collected at maximum solids content. And finally, to produce the greatest amount of salable product, in this case steam for the pulp or paper mill, the liquor must be burned efficiently.

A general statement has been made that this liquor can be burned at an efficiency somewhere about 10 per cent less than the commercial fuel presently employed in an existing boiler. Actually in these tests, a liquor only burning efficiency has been achieved of about 74 per cent. The boiler unit used regularly operates, on coal, in the neighborhood of 83 per cent. The difference is occasioned mainly by the additional moisture in the liquor which must be evaporated in the furnace and superheated to the exit gas temperature. Fig. 8 shows what this unavoidable loss amounts to in terms of the cost of coal and what the evaporated liquor must cost to produce the same amount of steam at the same cost.

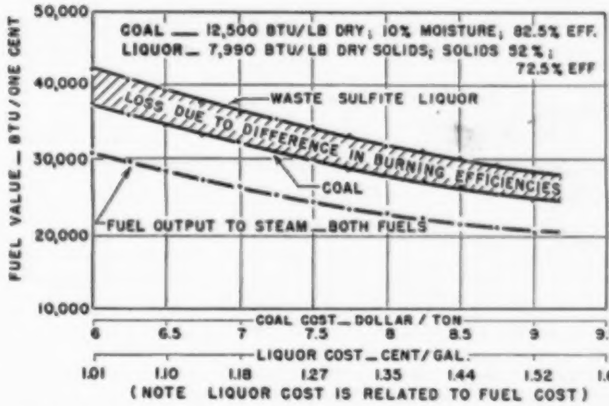


Fig. 8—Showing loss due to difference in burning efficiencies

It is not within the scope of this discussion to attempt to describe either the systems for collection and evaporation or the problems connected with the operation of such systems. It may be pointed out however, that a 100-ton sulfite mill will produce enough heat units after the liquor has been reduced to 52 per cent solids content, to make in the neighborhood of 40,000 lb of high-pressure, high-temperature steam per hour. In most cases, this steam would be passed through a back-pressure turbine and some electrical energy obtained. Up to roughly one-half of the low-pressure exhaust steam from the turbine will be required to prepare the liquor for burning, leaving a steam balance and a quantity of electrical energy which can be evaluated against that produced by the commercial fuel in use. In this way the economic position of an installation can be computed.

Facts and Figures

The principal constituents of fly ash are oxides of silica, aluminum, iron and calcium.

•

The United States possesses approximately a third of the world's railroad trackage.

•

The largest steel producing company now produces about a third of all the steel made in this country.

•

When burning pulverized coal, best results require a minimum of plus 50-mesh material.

•

Production of electric energy by utilities for the 12-month period ending May 31 passed the 300 billion kilowatt-hour mark for the first time.

•

It has been found that silica concentrations in boiler water, in excess of 5 ppm, will cause deposits on turbine blades.

•

With traveling grate stokers burning bituminous coal optimum results are usually obtained at combustion rates from 30 to 40 lb per sq ft per hr.

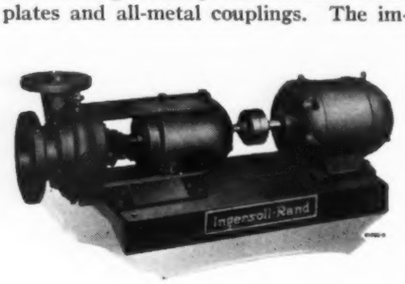
NEW EQUIPMENT

Bucket-Elevator Chains

Beaumont Birch Co., Philadelphia, Pa., has announced the availability of Beaucalloy elevator chains made of a heat-treated alloy steel. Among the design features are projecting guards which deflect material from chain joints, slotted boss ends which prevent pin from rotating and protect cotter pin from wear, connecting pins of heat-treated steel and having a centerless ground finish, and a single link barrel cast integrally with side bars. It is said that these alloy-steel chains have greatly increased service life over malleable iron chain.

Cradle-Mounted Pumps

A new line of cradle-mounted centrifugal pumps, announced by Ingersoll-Rand Co., Phillipsburg, N. J., incorporates such design features as deep water-cooled stuffing boxes, smothering glands, ring oil lubricated ball bearings, heavy cradle shafts and bearings, sturdy channel-steel baseplates and all-metal couplings. The im-



peller is mechanically and hydraulically balanced. The pumps are built in five different sizes, ranging from $^{3}/_{4}$-in. to 5-in. discharge with capacities up to 1600 gpm and heads up to 250 ft, single and two stage. Power requirements range from $^{1}/_{4}$ to 75 hp, and the pumps are suitable for paper mills, breweries and distilleries, chemical plants, refineries, building and contracting and general manufacturing process.

Heat-Exchangers

A new line of standardized exchangers featuring all-cuprous, removable tube-bundle construction is now in quantity production by Ross Heater & Mfg. Co., Buffalo 13, N. Y. Originally designed for service on Navy combat vessels, the Type

BCP exchanger has been adapted to low-cost quantity production. By embodying larger transfer service, a smaller, less expensive unit now serves the same conditions that formerly required larger, costlier sizes.

Platform Hoist

Painting, repairs and inspection of elevated work are facilitated by the new foot-operated "Bosun's Chair" manufactured by Safway Steel Products, Inc., Milwaukee

13, Wis. It consists of a rigid tubular steel cage moved by a winch. Sitting on a bicycle-type saddle having two coil springs, the worker operates standard bicycle pedals to raise or lower the hoist. Power is transmitted from the pedal crank to the winch drum by means of a roller chain, running on sprocket wheels which are arranged in a ratio that permits operation with minimum effort. Movement of the hoist in either direction may be as fast as 25 ft per min, and the chair has a rated capacity of 625 lb.

Metal Coating Materials

Three new materials for coating metals have been announced by The Dampney Company of America, Hyde Park, Boston 36, Mass. Vinyl Coating is recommended for service over an operating temperature range of −40 F to 160 F, wet or dry; it is resistant to alkalies and mineral acids, is insoluble in alcohols, greases, oils and aliphatic hydrocarbons, and has low permeability to water vapor and low water absorption. An applied film of this material is non-flammable and imparts neither taste, odor nor toxicity.

Dampney Metal Primer is a new vinyl resin formulation for pretreatment of metal scheduled for water-submerged service. The material serves to inhibit corrosion temporarily prior to finish coating and to improve bonding for the appropriate surfacing material that is to be applied. It is recommended in combination with Apexior for service in water-storage tanks, condensers, locomotive tenders, and wherever metal is exposed to fresh or salt water at temperatures to 140 F.

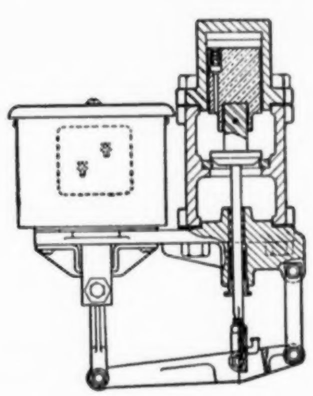
Dampney Silicone Coating is intended for weather-exposed surfacs, utilizing the characteristics of silicone resins in combining high inertness and heat stability. It is recommended for application to stacks, furnaces, boilers, heaters, steam lines and gas burners.

Steam Trap

The Yarnall-Waring Company, Philadelphia 18, Pa., has improved the design of the Yarway Impulse Steam Trap by using a stainless steel body in place of the cold-rolled-steel, cadmium-plated body previously furnished for working pressures up to 400 psig and temperatures up to 450 F. This design provides additional resistance to the abrasive wear and corrosion encountered in severe steam trapping service. As before, internal parts of the traps are made of stainless steel alloys.

Solenoid Valve

To eliminate water hammer resulting from sudden closing of a valve in a high-velocity pipe line, the Johnson Corporation of Three Rivers, Mich., has developed a special dash pot design for its direct-operated solenoid valves. This arrange-



ment, which slows down the closing action of the valve $1^{1}/_{2}$ to 2 seconds, is suitable for temperatures up to 400 F and in smaller sizes will operate under differential pressures up to 150 psi. It is available in sizes of $^{3}/_{4}$, 1, $1^{1}/_{4}$, $1^{1}/_{2}$ and 2 inches.

Recording Turbidimeter

A new photoelectric instrument which automatically measures and records the amount of suspended particles in a liquid has been announced by the Special Products Division of the General Electric Co., Schenectady 5, N. Y. The recording turbidimeter, as it is known, provides a

means for monitoring and controlling processes in water-treatment plants. It operates on the principle that turbidity of a liquid varies in direct proportion to the ratio of scattered light to transmitted light through the liquid.

Vacuum Pump

Kinney Manufacturing Co., Boston, Mass., has brought out a new, small compound vacuum pump, Model CVD 3534. Employing an oil-seal pumping system, the pump has a free air displacement of 4.9 cu

ft per min and operates with a $^1/_3$-hp motor. On a test basis each unit is required to produce a gage reading of 0.001 mm Hg or better. In physical size the vacuum pumps is less than 16 in. in height and is constructed in a manner that permits easy servicing.

Water Conditioner

Cochrane Corporation, Philadelphia, has made available a new type of water-softening equipment which combines advantages of the hot-process and zeolite softeners. In the hot-process-zeolite water conditioner the zeolite softener is used as a second stage following the first stage in which lime is the single reagent. The first stage precipitates the bicarbonates and magnesium in the water supply, leaving the remaining hardness to be removed from the zeolite softener which uses salt as a regenerant.

Arthur Ludt Passes

As we go to press word has been received of the death on July 12 of Arthur Ludt, a contract engineer for Combustion Engineering–Superheater, Inc. A native of Elizabeth, N. J., Mr. Ludt was fifty-six years of age and attended Newark College of Engineering. Prior to joining the engineering department of Combustion in 1919, he had been employed by the Singer Sewing Machine Co., the Babcock & Wilcox Co., and the Wheeler Condenser & Engineering Co. In his capacity as contract engineer Mr. Ludt was associated with some of the largest central-station projects and was widely known in the power field.

Business Notes

Peabody Engineering Corp., New York, has opened a Chicago Office with Allen H. Jones as manager.

Air Preheater Corp. has appointed W. H. Larkin to its sales organization in New York. Mr. Larkin was formerly with the Sturtevant Division of Westinghouse Electric Corp.

The Wm. Powell Company, Cincinnati valve manufacturer, has appointed Robert J. Wigg as its sales-service representative in the Pacific Northwest with headquarters in the Builders Exchange Building, Portland, Ore.

E. F. Drew & Co., water specialists, New York, has recently appointed Tomas S. Agramonte, a manufacturers' agent with offices in the Pan American Airways Building, Havana, as its Cuban representative in the sale of evaporator and boiler water treatments.

Manning, Maxwell & Moore, Inc., announces the appointment of Erling Klafstad as assistant director of engineering for its Hancock valves and Consolidated safety and relief valves. Mr. Klafstad was formerly in charge of engineering and manufacturing for the Crosby Steam Gage and Valve.

E. W. Nick, formerly president of **Northern Equipment Co.,** Erie, Pa., a division of Continental Foundry & Machine Co., has been elected chairman of the board, his place having been filled by G. L. Davis, president of the Vulcan Soot Blower Division of Continental, who will also continue to serve in that capacity.

Among recent appointments announced by **General Electric Co.** are Francis E. Fairman as general sales manager of its large apparatus divisions; Arthur W. Bartling, general sales manager of its small apparatus divisions; Robert S. Neblett, assistant manager of sales of the turbine divisions, and Frank A. Faron, New York district industrial divisions manager.

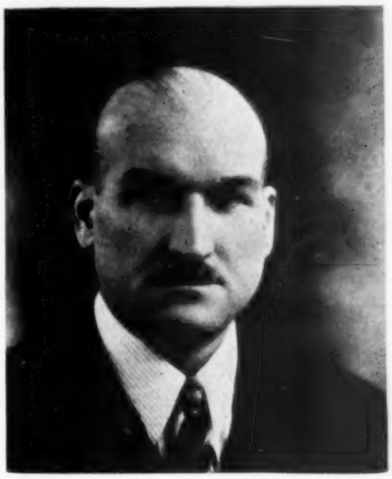
Combustion Engineering-Superheater, Inc., announces the following appointments: Frank J. Murphy, formerly production manager of its Chattanooga Division to general purchasing agent of the Company in New York; B. A. Anderson as production manager in New York; and Myron F. Freeman as manager of the Service and Erection Department, succeeding the late Terrell H. Walker.

Yarnall-Waring Co., Philadelphia manufacturers of steam plant equipment, announces the following appointments in the Yarway sales organization: Lytton C. Musselman in charge of Los Angeles district at company office in Huntington Park, Calif.; Power Engineering Company as general sales representative in Salt Lake City; Wallace J. Agren as sales engineer in Chicago branch, replacing F. C. Harry Vaughan, deceased; R. W. Westlake as sales engineer in Cleveland branch; Andrew M. Ritter, district manager of Detroit branch, replacing Charles H. Grosjean, who is returning to the New York territory. Lyle G. Chase, Jr., has joined the sales engineering staff of the New York district office.

Obituary

Leonard H. Birkett, general sales manager of Combustion Engineering Corp. Ltd. (Canada) since 1933, died at his home in Montreal on June 28 at the age of 59. A well-known figure in the railway and industrial fields throughout Canada, Mr. Birkett served as a captain in the Royal Canadian Engineers in World War I and was employed by the Canadian Locomotive Company, Ltd., and the Canadian Pacific Railway Company prior to joining The Superheater Company, Ltd., in 1921, where, until his death, he served as sales manager of the Industrial Division.

He was a member of the United Services Club, Canadian Railway Club and The Engineering Institute of Canada.



Personals

Dr. A. A. Potter, dean of engineering at Purdue University, has been elected to the presidency of Bituminous Coal Research on a part-time basis.

Prof. Theodore Baumeister, specialist in power problems in the Columbia University School of Engineering, has been appointed to the Stevens Professorship of Mechanical Engineering at that university where he has been a faculty member since 1922.

Prof. Harry J. Loberg has been appointed director of the Sibley School of Mechanical Engineering at Cornell University, succeeding Prof. W. J. King, who resigned to accept a teaching position at the University of California in Los Angeles.

R. E. Ginna has been named executive vice president of the Rochester Gas & Electric Corp. He previously had been vice president in charge of sales and regulatory matters.

Henry B. Oatley, for many years vice president in charge of engineering for The Superheater Company, New York, and until recently chairman of the A.S.M.E. Boiler Code Committee, was awarded the honorary degree of Doctor of Engineering by the University of Vermont on June 12. He had been similarly honored by Stevens Institute of Technology last February.